Electrical Engineering

October
1939

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For Indoor or Outdoor Use
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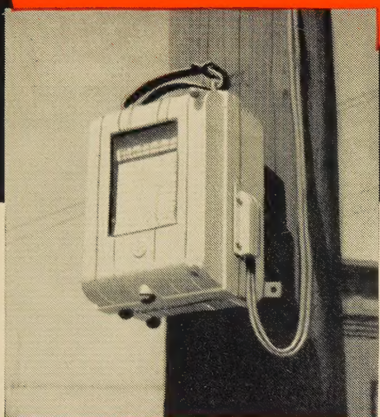

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GENERAL ELECTRIC

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Transactions Section *(Follows EE page 446; a preprint of pages 499-562 of the 1939 volume)*

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High Lights

Cable Ratings. The most efficient use of impregnated-paper-insulated lead-covered cable may require occasional emergency loads in excess of ratings specified in standards. Possible shorter cable life and higher losses must be balanced against the cost of larger conductors; cable life depends on the limitations of the insulation and of the sheath, and the heating characteristics of the conduit. One system has established emergency load ratings for cables operating from 120 to 132,000 volts (*Transactions pages 535–56*). A study of the effect of intermittent operation of paper-insulated 15-kv cables at temperatures above the level generally accepted as maximum for their class indicates that modern types of cable that permit expansion and contraction of the cable compound without unduly stressing the lead sheath could be operated repeatedly to copper temperatures as high as 100 degrees centigrade (*Transactions pages 556–62*).

Engineering and Social Problems. Because engineering achievements have resulted in so many contributions to society, many believe that engineering methods can be applied equally successfully to social problems. In an article discussing this general subject, the engineer is urged to do what he can to educate and warn the lay public that principles applicable to his inanimate problems cannot be applied directly in the realm of social phenomena (*pages 423–6*).

Transactions Supplement. A special supplement, containing 28 technical papers which will be included in the 1939 annual volume of AIEE TRANSACTIONS but which have not been preprinted in the monthly TRANSACTIONS sections of ELECTRICAL ENGINEERING, will be published in December. Abstracts of the papers included in the supplement appear in this issue (*pages 432–5*).

Traveling-Wave Demonstrator. A device has been built by means of which various types of surges on power transmission lines readily may be visualized. Not only does it aid in gaining an understanding of the nature of these phenomena, but from the results obtained with it important fundamental theoretical relations may be deduced (*pages 414–20*).

Steam-Electric Locomotive. The railroads' newest aid toward faster schedules is the 5,000-horsepower steam-electric locomotive recently placed in service on the Union Pacific System. Each of the two 2,500-horsepower units consists of an electric locomotive with its own high-pressure condensing steam-electric generating plant on board (*pages 407–13*).

Motor Rating. A revised method of rating single-phase motors for compressors for refrigerating machines has been suggested, in order to specify more clearly the motor characteristics for applications where torque rather than temperature is the important consideration (*Transactions pages 519–27*).

Transformer Loading. A method of loading a transformer according to copper temperature as determined by a thermostatic relay utilizes the latent overload capacity of the transformer to permit it to supply overloads until its maximum safe temperature is reached (*Transactions pages 504–14*).

Ratings. Technical, economic, and psychological aspects are involved in the methods of rating electrical machinery and apparatus. Better agreement of existing standards with present-day conditions could be obtained by some modifications (*Transactions pages 499–503*).

New Commitee Chairmen. New chairmen for 1939–40 were appointed for 16 of the Institute's committees, and began their duties August 1. Biographies of a majority of the new chairmen will be found in the Personal Items section of this issue (*pages 443–5*); others in subsequent issues.

Voltage-Regulation Computations. Determination of voltage regulation for four-winding transformers, with load on three windings and the fourth acting as a source, may be simplified by the use of constants obtained directly from the usual two-terminal impedances (*pages 420–1*).

News 436

Temperature Effects. One factor limiting the output of electrical rotating machinery is the rise in temperature that can be tolerated without damage to the machine from distortion of parts and melting of soldered connections (*Transactions pages 514–18*).

Section Activities. Abstract of the report on activities of local AIEE Sections, presented by Chairman H. H. Race at the 1939 summer convention, is published in this issue, with a chart showing results of the Sections committee's survey (*pages 436–7*).

Electricity as a Fire Hazard. Statistics accumulated by one insurance organization show that electricity rates as a strong first contender as fire hazard in industrial plants, with one out of every five industrial fires of electrical origin (*page 427*).

Voltage for Airplanes. Calculations show that for a wide variety of airplanes of different types the voltage for the electrical systems may advantageously be standardized at 24 volts (*pages 428–31*).

Why So Few Famous Engineers Today? This question is asked by a well-known engineer who has summarized some of the answers that have been suggested to him (*page 422*).

Welder Control. Precision control of resistance spot welders is offered by a simplified unit consisting of a synchronous magnetic contactor and a motor-driven timer (*Transactions pages 528–34*).

Coming Soon. Among special articles and technical papers now undergoing preparation for early publication are: an article on vertical-shaft generators, discussing some of their problems and methods of solution, by H. R. Sills (M'31); an article on lightning strokes in field and laboratory, by P. L. Bellaschi (M'34); a paper on induced current in parallel circuits and its effect upon relays by E. H. Bancker (M'30); a paper describing an amplifier-wattmeter combination for the direct measurement of watts and vars by G. S. Brown (A'33) and E. F. Cahoon (A'34); a paper on high-speed-relaying experience and practice by the relay subcommittee of the AIEE committee on protective devices; a paper on emergency ratings by A. H. Kidder (A'29); a paper on the factors affecting arc extinction on a Petersen-coil system by J. R. Eaton (M'35); and a paper describing operating experience with Petersen coils on the 66-kv system of the Metropolitan Edison Company in Pennsylvania by H. M. Rankin (M'22) and R. E. Neidig (A'38).

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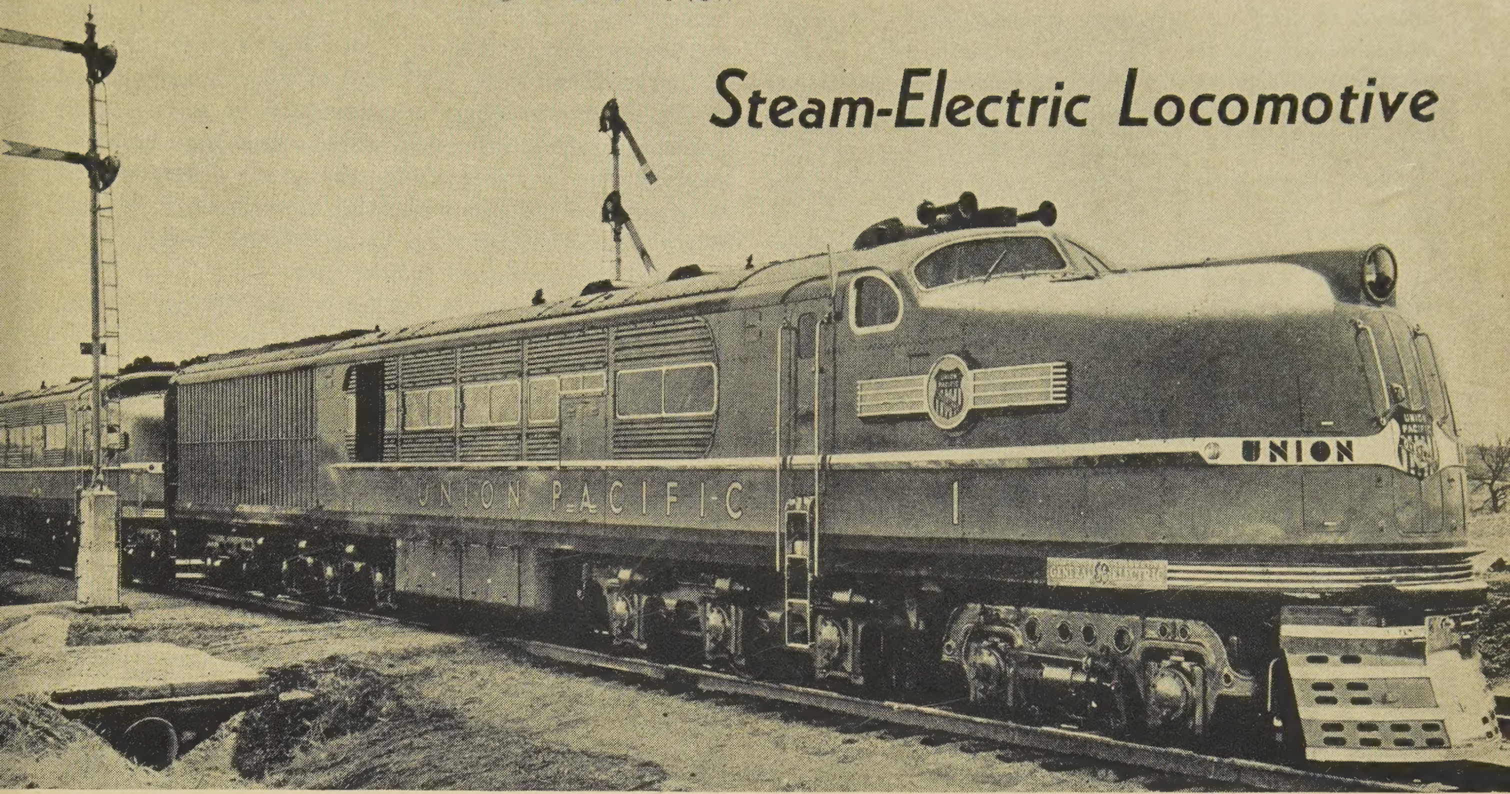
UNION PACIFIC'S New Steam-Electric Locomotive



The need for faster railroad schedules has necessitated the development of new motive-power units capable of sustained high-speed operation. Newest entrant in that realm is the steam-electric locomotive recently placed in operation by the Union Pacific Railroad.

RAILROAD transportation has been one of the most important factors in the development of the United States and in welding together all its parts into a single nation. All sections of the country have been made accessible by the railroads, and transportation costs have been such that the people of all parts have been able to keep in continuous contact with each other. In recent years, however, automobiles, airplanes, and other new forms of transportation have presented new problems to the railroads. Solution to those problems has been the development of high-speed light-weight rolling stock, which has enabled the railroads to establish faster schedules without the necessity of making expensive alterations in track construction.

About 1932, a special investigation and study was made by the Union Pacific Railroad to determine what could be done to keep its passenger transportation abreast of the times. The results of these studies indicated a need for a radically different type of passenger equipment. At that time, fast steam passenger trains required three nights and two days to run from Chicago, Ill., to the Pacific Coast points of Los Angeles and San Francisco, Calif., and Portland, Ore. It was considered desirable to reduce this time to two nights and one day, but it was not considered possible to accomplish this with the standard steam locomotives then available. After much study and experimenting, it was decided to build a light-weight train consisting of an oil-electric locomotive and new light-weight passenger cars. To reduce wind resistance at high speeds, the train was streamlined.

Before the first oil-electric train was completed, which included three passenger cars and was powered by a 600-horsepower engine, construction on a 6-car Diesel-electric train was started. Since then larger and more powerful Diesel-electric trains have been built and placed in operation, not only on the Union Pacific but on many other roads, providing these roads with a new tool to meet the competition offered by the newer forms of transportation. The latest train of this type consists of 17 cars and is propelled by a three-unit 5,400-horsepower locomotive.

With the use of the Diesel-electric locomotive, it is possible to use one locomotive all the way from Chicago to the Pacific Coast, instead of five or six as was the practice with steam locomotives. Furthermore, it is possible to increase the fueling and watering points to about 500 miles, thus reducing the stops for this purpose from about 25 to 5.

About five years ago, the General Electric Company began investigating the possibilities of building a steam-turbine locomotive that could be used not only in general

In addition to the results of a firsthand inspection of one of the units of this locomotive, information for this article has been drawn from various authoritative sources, including the railroad company and the manufacturing company principally involved in the development of this significant new motive-power unit. Special credit is acknowledged to the ASME paper by B. S. Cain and A. J. Woodward made available through the courtesy of ASME Editor G. A. Stetson, and the AIEE paper by M. R. Hanna and J. F. Tritle which, together with other references that will serve the reader seeking more details, are listed at the close of the article. The effective assistance of Vice-President H. L. Andrews, Engineer C. M. Davis, and Statistician W. D. Bearce of the General Electric organization in supplying and verifying data likewise is gratefully acknowledged.

railroad service, but also for hauling high-speed passenger trains. Sometime later the Union Pacific also investigated the possibilities of this type of motive power and finally arranged to have a two-unit 5,000-horsepower locomotive of that type constructed. Culminating more than two years of co-operative design and research by scientists, engineers and officials of the railroad and of various manufacturers, this locomotive, which recently was completed and placed in operation, provides the railroads with a new aid to faster schedules and marks another milestone in railroad history.

Each of the two 2,500-horsepower units comprising the 5,000-horsepower locomotive has all the attributes of a straight electric locomotive, and in addition carries its own high-pressure steam-electric generating plant to supply the electric energy required. The locomotive was designed to haul a train of 1,000 trailing tons from Chicago, Ill., to the Pacific Coast by operating the two units in multiple-unit fashion, or either unit may be operated separately to haul a train of half that weight. Maximum speed is 125 miles per hour.

Operating conditions on the Union Pacific System are quite severe. Temperatures vary from −40 to 115 degrees Fahrenheit. Elevations vary from sea level to more than 8,000 feet, and dust imposes a serious problem in some sections. The system also traverses regions in which good water is difficult to obtain. The steam-electric locomotive meets the last difficulty admirably, as the steam plant is a closed condensing system containing less than 3,000 pounds (340 gallons) of water, and requires very little makeup. During the heating season the big demand for water is for steam for train heating, for which a capacity of 3,000 pounds per hour is provided. Each 2,500-horsepower unit carries but 4,000 gallons of raw water—only 1/20th as much as a comparable side-rod steam locomotive. Runs of from 500 to 700 miles may be made without stopping for either fuel or water.

The locomotive is completely controlled from the operator's cab of either unit. Acceleration control may be either automatic or manual, as desired. Under automatic operation, the operator may pull the controller handle immediately to the highest speed position, or to any intermediate position, and the control will accelerate the train at the maximum rate, switching motor connections and raising the motor voltage automatically so as to use all available power at all times. Steam flow from boiler to main turbine is governed by the power demand; feed water, fuel oil and combustion air are controlled in turn by the steam flow, all three being supplied from a single turbine-driven combined auxiliary set.

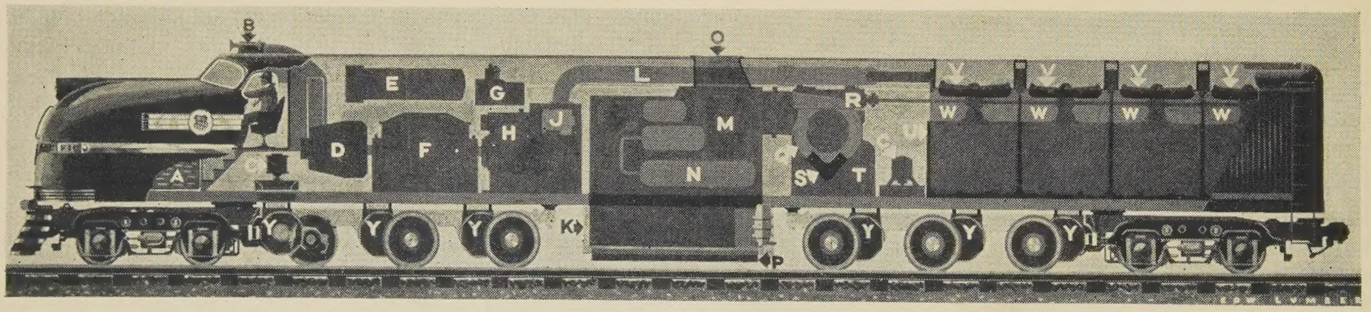
To obtain the capacity, flexibility, and efficiency essential to the best train-operating characteristics, the equipment has been designed to respond promptly to sudden demands for power. For example, following a sudden demand for full output from no load, the boiler pressure may drop to about 1,300 pounds per square inch, but will recover to full rated pressure of 1,500 pounds in less than two minutes, even though under load.

Electric braking is provided, the six propulsion motors on each unit acting as generators and feeding into a water-cooled resistor. It may be used either alone or in combination with train brakes during normal stops or slowdowns, and is particularly advantageous when descending long grades. For example, electric braking has held the locomotive and a trailing train of 1,000 tons on a long 2.2-per cent grade without any application of the air brakes.

General Design of Locomotive

Arrangement of the principal equipment on the steam-electric locomotive is shown in an accompanying illustration. The essential parts of each unit are:

1. A high-pressure oil-burning steam boiler.
2. A turbine-driven auxiliary set to supply feed water, combustion air, and fuel oil to the boiler.
3. Complete automatic control for supplying adequate steam as demanded.
4. A main geared d-c turbine generating set for traction power.
5. An a-c generator on same shaft for train air conditioning, traction motor blowers, and other accessories.
6. Air-cooled condensers for returning used steam to boiler as water.
7. Six axle-hung traction motors geared to main drivers.



Phantom view of locomotive showing general arrangement of parts

A—Raw-water tank
B—Vertical headlight
C—Traction-motor blowers
D—Air-conditioning alternator
E—Train-heating evaporator
F—Main generators
G—Air-brake compressor
H—Reduction gear
J—Main turbine
K—Main control contactors
L—Exhaust header
M—Boiler
N—Feed-water heater
O—Stack
P—Braking resistors
Q—Boiler draft fan
R—Condenser-fan turbine
S—Feed-water pump
T—Boiler-auxiliary-set turbine
U—Fuel tanks
V—Condenser fans
W—Air-cooled condensers
Y—Traction motors

8. Main control system for automatic and manual control of motor combinations during acceleration.

9. Braking-control system which automatically or manually blends electric braking with air braking.

10. Electric couplers and accessories which permit operating the locomotive units singly or in multiple-unit fashion during acceleration and braking.

11. Three separate train-control signal systems to conform to the requirements of the different lines over which the locomotive will operate.

Steam Plant and Cycle

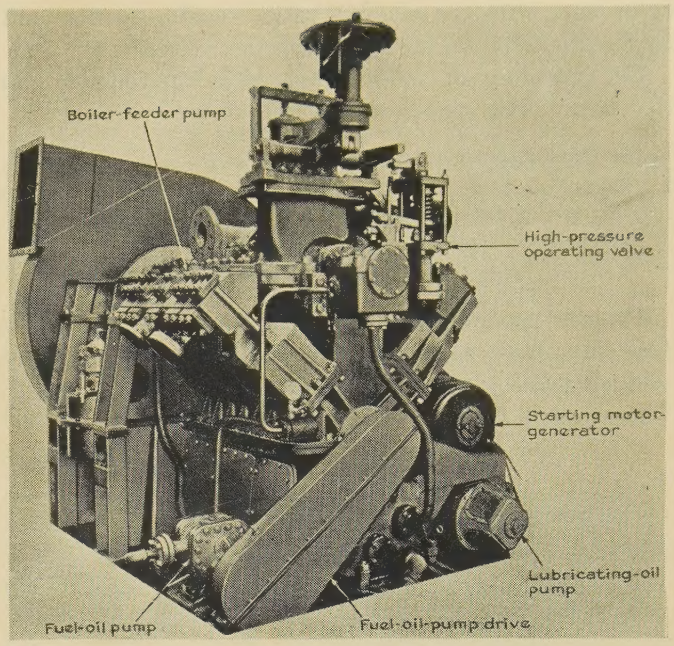
The boiler delivers steam at a pressure of 1,500 pounds per square inch and a temperature of 920 degrees Fahrenheit; it is fired by two vertical oil burners using a low grade of fuel oil known as "bunker C" oil. The furnace has water-cooled walls consisting of six circuits of carbon molybdenum steel tubes coated with refractory. After leaving the furnace, the gases pass through a screen section and up through the economizer, superheater, and air heater to the stack.

From the boiler, steam goes to the main turbines and then to the condensers. The condensate drains to a low-level tank, from which it is pumped to a high-level tank. The high-level tank feeds by gravity into a booster pump which supplies the main high-pressure feed pump. This feed pump returns the condensate through a three-stage feed-water heater to the boiler.

Steam is extracted from the first stage of the high-pressure turbine to drive the auxiliary turbine and condenser-fan turbine, which are connected in series and exhaust into the main condenser. First-stage extraction steam also is used to heat an evaporator supplying make-up and train-heating steam. When insufficient extraction steam is available for these purposes, high-pressure steam

Summarized Data for Each 2,500-Horsepower Unit of Union Pacific-General Electric Steam-Electric Locomotive

Wheel arrangement	2-C-C-2
Total weight with full tanks of fuel and water, pounds	548,000
Weight on driving wheels, pounds	354,000
Weight per driving axle, pounds	59,000
Fuel-oil capacity, gallons	3,000
Water capacity, gallons	4,000
Total length over couplers	90 ft. 10 in.
Over-all width (including grab handles)	10 ft. $8^3/_4$ in.
Maximum height above rail	15 ft. $^3/_4$ in.
Maximum rigid wheelbase	13 ft. 4 in.
Diameter of driving wheels, inches	44
Diameter of guiding wheels, inches	36
Rated output of main turbine for traction, horsepower	2,500
Turbine speed (constant), revolutions per minute	12,500
Gear reduction to generator shaft	10.4/1
Boiler steam pressure, pounds	1,500
Total steam temperature, degrees Fahrenheit	920
Water in closed boiler-condenser system, gallons	340
Rated output of evaporator for train heating, pounds per hour	3,000
Generator speed, revolutions per minute	1,200
Maximum generator voltage (2 armatures in series)	1,340
Maximum generator current, amperes	3,200
Number of traction motors	6
Weight of each traction motor (less gearing), pounds	10,500
Nominal rating of each traction motor, horsepower	600
Traction motor gear ratio	2.097/1
Starting tractive effort, pounds	86,500
Continuous tractive effort:	
24 miles per hour, pounds	32,000
60 miles per hour, pounds	13,050
100 miles per hour, pounds	7,520
Maximum braking effort available, pounds	35,000
Braking resistor, power absorption capacity, kilowatts	3,600
Maximum permissible speed, miles per hour	125



End view of boiler-auxiliary unit

automatically is supplied through the auxiliary set and evaporator-control valves.

Three additional extraction lines from the main turbine are used for feed heaters and for controlling the auxiliary-set and condenser-fan turbines. Vacuum is obtained by two ejectors operated from evaporator steam. The condensate pump also feeds the water-cooled braking resistor. Pressure required to force the water through the tubes of the braking resistor is obtained by two injectors using high-pressure steam, and the resistor discharges into a separator .rom which water returns to the low-level condensate tank and steam to the main condensers.

The closed system contains less than 3,000 pounds of water and, under full load, the water completes the cycle in about $3^1/_2$ minutes.

Steam Control

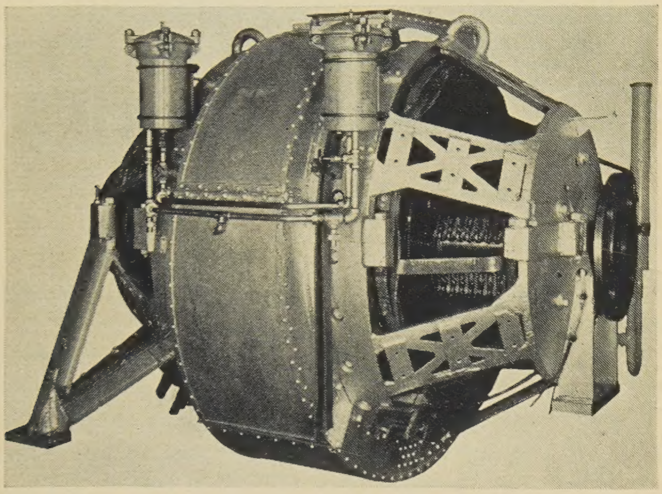
The amount of water delivered to the boiler is determined primarily by the steam flow, as measured by a steam-flow meter. This measurement is used to control the auxiliary-turbine steam valve and thus controls the speed of the feed-water pump and hence its output. As a further check, the water level in the separating drum is measured and this measurement, serving as a final correction on the water flow, also is relayed to the auxiliary turbine. The fuel-oil pump and combustion-air blower are both driven by the same auxiliary turbine that drives the feed-water pump. They are proportioned so that for a speed suitable to deliver the required quantity of water, they will deliver an excess of oil and air above the quantities required to generate steam from that water. The excess capacity is throttled, the oil by a valve and the air by a damper which has its position modified in accordance with steam pressure. The fuel-oil valve is controlled in

accordance with the metered ratio between oil flow and air flow to maintain proper combustion conditions.

The continuity of combustion is under the control of an electric circuit arranged to:

1. Ignite or extinguish the fire in operating.
2. Shut off the fuel in the event of high steam pressure, high steam temperature, flame failure from any cause, or failure of water supply or lubricating-oil supply to the feed pump.
3. Re-ignite the fire when normal conditions are established.

Propane gas ignited by spark plugs serves to ignite the fuel oil. With all conditions normal, the propane is ignited and after a few seconds the fuel-oil valve is opened. Photoelectric cells located to receive light from the oil fire operate to shut off the igniting torches when normal fire is established. They also shut off the fuel supply and initiate a normal igniting cycle in case the fire goes out. In cases such as lack of fuel oil, the igniting cycle will repeat four times, then lock out until manually reset.



Main double-armature 2,500-horsepower generator

The time required to build up full steam pressure and make the locomotive ready for service is only 15 minutes. Hence, there is no need to use fuel to keep the locomotive hot when not in service.

In addition to the main boiler control, the automatic system maintains water level in the condensate tank, admitting steam from the evaporator to the closed system when the water is low, or returning water to the raw-water tanks when the level is too high. The condenser-fan speed is controlled automatically by the temperature of the condensate return from the condensers. The evaporator also has its own control, which maintains water level and steam pressure in the evaporator shell.

Boiler Auxiliary Set

The boiler auxiliary set is essentially a variable-speed unit, its speed depending on the load on the boiler; it is turbine driven and supplies feed water, combustion air, and fuel oil to the boiler. The turbine has a four-stage rotor and is geared to the feed pump and blower. The auxiliary set has a geared battery-operated starting motor which also acts as a generator driving the other motor pumps after the auxiliary turbine is on steam, in case the battery-charging set is not running.

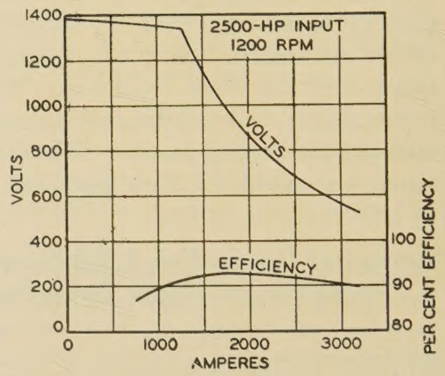
The steam condenser is built in 24 sections and mounted in the rear of each locomotive unit. Each section consists of vertical finned tubes between upper and lower headers. The sections are of two-pass design, the first pass being primarily for condensation of steam and the second pass primarily for cooling of air and vapor which are drawn off by the ejectors. The upper headers are thus divided into steam and air sections and the lower headers are drained to the condensate return lines.

Four 65-inch aphonic fans on each locomotive unit provide air to cool the condensers. The fans are driven from one turbine through a line shaft and four right-angle-drive gear boxes. The turbine, which takes steam from the auxiliary-turbine exhaust and discharges into the condenser, is mounted on the boiler auxiliary set. It is a 3-stage single-reduction-gear unit.

Main Turbine-Generator Unit

Four units comprise the main turbine-generator set; a geared turbine, a main d-c generator, an auxiliary alternator, and an exciter. The turbine is a two-cylinder ten-stage cross-compound machine with two pinions running on a common gear. Turbine rotor speed is 12,500 rpm, which is reduced to 1,200 rpm by the reduction gear. The geared turbine is connected through a flexible coupling to the main d-c generator.

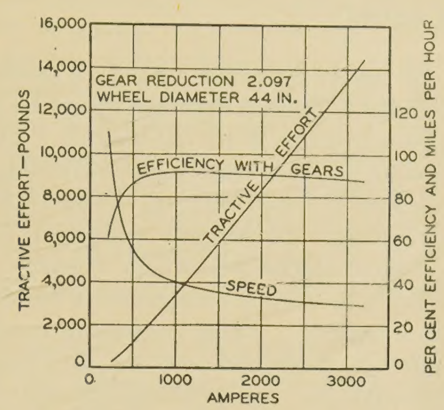
Characteristics of main 2,500-horse-power generator with speed control



A pair of complete generators built in a single frame with armatures back-to-back comprise the main d-c generator. To provide rigidity with minimum weight, the tandem armatures are built on a single hollow steel cylinder with stub shaft extensions at each end. To avoid excessive commutator surface speed, it was necessary to reduce the commutator diameter to a point that precluded passing the armature ventilating air under the commutators. Ventilation is effected through the risers, which are of the involute type to serve also as equalizers. The armature ventilating fan is mounted in the central space between the two armatures.

These two component generators built into one frame are normally connected in series with their midpoint

grounded, thus limiting the insulation stress in all the transmission equipment to not over half the total voltage generated. The traction generator unit is separately excited by a "metadyne," or variable-voltage, exciter, which, through a speed-sensitive control device and depending on the turbine power available, imparts to the generator output characteristics as shown in an accompanying graph. The electrical proportions of the machine are such that it



Characteristics of traction motor on 300 volts

will produce full horsepower continuously at any point shown on these characteristic curves, from some 1,300 amperes at 1,320 volts to 3,200 amperes at about 520 volts. Maximum generator voltage is 1,400 volts.

Auxiliary A-C Generator, and Exciter

The auxiliary a-c generator and the main-generator exciter are built into a compact two-unit machine having a centrally located ventilating fan and a single self-aligning antifriction bearing, the driven end of the set being supported on a steel disk type of flexible coupling through which the auxiliary unit is attached to a shaft extension of the main generating unit. The a-c machine is of the salient-pole-rotor design with distributed stator windings. The continuous rating is 480 kva, 230 volts, three phase, 60 cycles. It is of conventional design except for the use of class B insulation and aluminum frame to reduce size and weight. The primary purpose of the alternator is to supply lighting, heating, cooking, and air-conditioning power to streamlined passenger trains. On the locomotive it supplies two traction-motor blowers, the speed-control governor, the main air compressor, the 130-volt and 64-volt motor generator sets, and, through small transformers, the 12-volt headlights and part of the 115-volt lights.

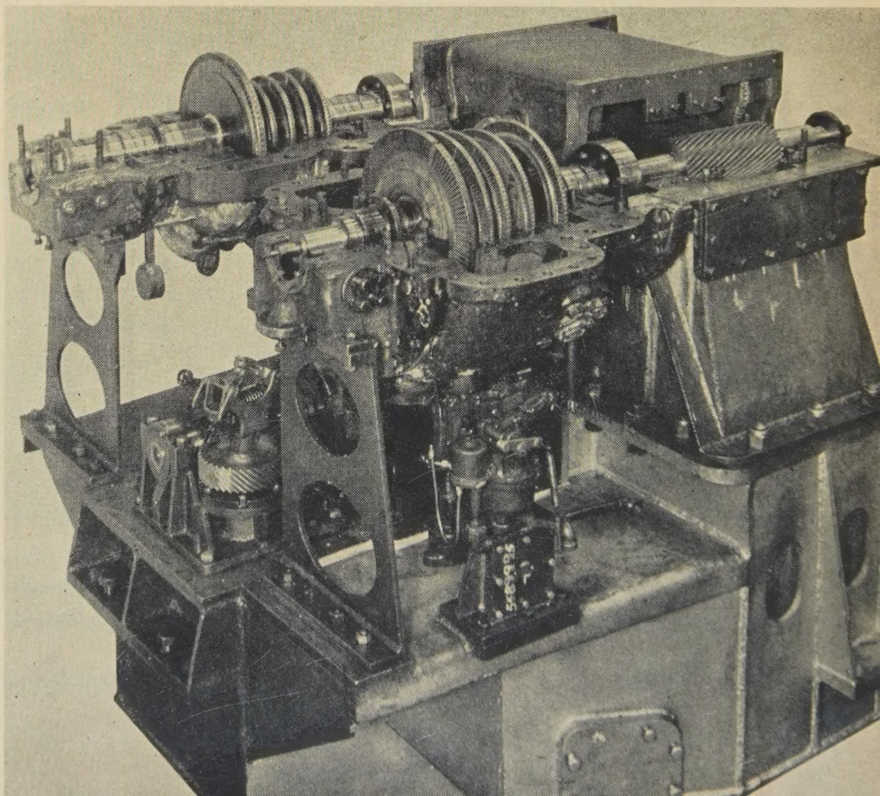
In common with all "metadyne" type machines, the exciter is characterized by armature excitation. One of its most valuable properties lies in its inherent characteristic of delivering a definite current output regardless of load-circuit resistance, the value of the current being approximately proportional to the current in one of its low-wattage control fields. This exciter has two distinct functions. During the normal operation of the locomotive as a propulsion unit, it excites the field of the main traction generator. However, in electric braking, the exciter output connections are transferred from the generator fields to the traction-motor fields. It is here (as well as for multiple-unit propulsion operation) that the inherent constant-current characteristics of this exciter are of special value, for while the resistance of the traction-motor fields may change due to variations in temperature, the braking characteristics remain essentially unaltered.

Traction Motors

A locomotive with a weight of 354,000 pounds on its six driving axles and an operating range extending from a maximum speed of 125 miles per hour at one extreme to a maximum tractive effort of nearly 90,000 pounds at the other, presents a broad problem in traction-motor design. As usual in traction motors, much of the design was dictated by the necessity of mounting the motors between the wheels on standard track gauge. Minimum weight is of paramount importance. The motors are axle mounted, thus permitting the use of small wheels (44 inches). This gives the lowest possible cab floor height and the maximum room for apparatus in the cab. Characteristics of the traction motors on constant voltage are shown in an accompanying graph. The motor has eight poles with multiple-wound fully equalized armature.

In service the motors operate on a constant-horsepower variable-voltage generator characteristic, and the six motors in each locomotive unit will transmit 2,500 horse-

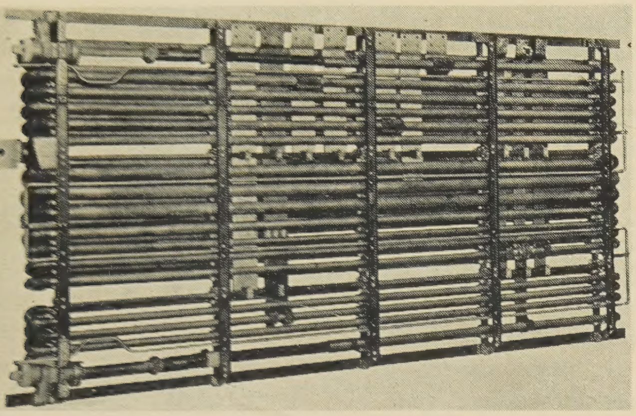
Main turbine and gear partially assembled; height of the portion shown is approximately five feet, which gives an indication of the compactness of the unit



power turbine output at any speed up to 125 miles per hour. Each motor is normally supplied with 2,000 cubic feet of cooling air per minute. The normal continuous rating is 32,000 pounds tractive effort per locomotive unit. To permit the handling of heavy trains in transcontinental service without the use of helper locomotives on heavy grades, high speed operation of the traction blowers is provided, giving 4,000 cubic feet of ventilating air per minute per motor. The rating obtained with this ventilation is 40,500 pounds tractive effort per locomotive unit.

Braking Resistor

Approximately 350 feet of seamless drawn stainless steel tubes through which cooling water is circulated comprise the braking resistor. These tubes are connected at the ends by cast return bends of the same material and the complete unit is assembled on insulated supports in the form of an oblong spiral. The tubing is arranged in two parallel hydraulic circuits with separate inlets and a common outlet which is rigidly grounded. Inlet pipes are insulated from ground by a special high-temperature molded tubing.



Water-cooled braking resistor; this is mounted horizontally underneath the locomotive

Ahead of each insulator tube is mounted an injector, supplied by steam from the main boiler and designed to force the cooling water through the braking resistor. The resistor has capacity to dissipate 3,600 kw continuously, but this maximum rating is used only when decelerating trains from maximum speeds. When braking at maximum capacity, approximately half the cooling water is converted into steam and the mixture passes through a steam separator; the water is returned direct to the hot well and the steam is passed into the main condenser.

Miscellaneous Electrical Equipment

Other electrical or electrically driven equipment on the locomotive includes:

1. A two-stage air compressor having a piston displacement of 186 cubic feet per minute to furnish air for braking and control apparatus; this unit is driven by a three-phase 60-cycle 220-volt induction motor, through herringbone gearing.
2. Two d-c motor-driven compressors with a combined piston displacement of 36 cubic feet per minute to charge the control system for initial start of the locomotive before steam is generated, and to assist in supplying air to the main reservoir when demands are heavy.
3. A 40-kw 130-volt d-c generator driven by a three-phase induction motor for charging storage batteries, supplying electrical control, boiler control, miscellaneous pumps, and other auxiliary circuits.

Control

A master controller with three mechanically interlocked handles to prevent improper operation controls all the main power circuits of the locomotive. The motoring handle operates a cam shaft and control fingers which vary resistance in series with the exciter field and establish the circuit for the magnet valves of electropneumatically operated contactors which connect the main traction motors in various combinations required for accelerating and braking. These contactors connect the motors in three speed combinations of 6, 3, or 2 motors in series, with provision for two speed combinations of 4 and 2 in series with any pair of motors cut out. Transition resistors are used to prevent interruption of power to the motors during transfer of the motors from one combination to another.

The brake handle drives its control cylinder through a long spring mounted concentric with the operating shaft. When this handle is moved into any one of the 20 notches on its dial ring, the spring will exert a torque to turn the control cylinder through the gear and sector at the bottom of the controller to the position selected on the dial ring. The movement of the cylinder, however, is governed by the notching mechanism engaging the notched wheel on the end of the shaft. The notching mechanism is controlled by current and kilowatt relays connected in the motor circuits during the braking cycle.

A seven-position selector handle governs the various series and parallel traction-motor connections for both forward and reverse directions. When accelerating the train from rest, this selector handle is moved to the "parallel" position, although with the automatic control in operation the motors actually are connected in series when starting from rest; the motoring handle then is moved slowly through the first few notches to take up slack and get the train into motion, after which it may be advanced as rapidly as desired up to the last, or 21st position. The movement of the motoring handle cuts out sections of fixed resistance in series with the field of the exciter. However, the exciter field current is limited by the automatic load-regulating equipment which takes control as soon as the motoring handle cuts out sufficient resistance to permit regulation at all output. Transition of the motors from series to series-parallel and from series-parallel to parallel takes place automatically under the control of a voltage relay when the generator voltage reaches the proper predetermined value. If it is desired to start and operate a train at less than full speed, the selector handle may be placed either in the "series" or "series-parallel" position, which prevents the motors from transferring to the next highest speed combination. The

main handle, of course, may be notched backward or forward at will to maintain any desired train speed.

If for any reason the operator wishes to eliminate the automatic features, a switch may be thrown which bypasses the automatic devices and cuts out the automatic transitions.

Braking may be controlled either manually or automatically. Manual control of the electric brake is provided to permit its use for slowing down the train and for controlling the speed on grades without the use of air brakes. This arrangement permits keeping the air brakes in reserve when descending long grades and relieves the wheels and brake shoes of considerable duty during slowdowns, particularly from high speeds. The advantages of such operation are apparent both from the standpoints of safety and brake maintenance. When curves permit, it is also possible to descend grades at higher speeds with safety because the air brakes are in reserve for stopping in an emergency.

The locomotive is equipped with "automatic air-brake control equipment" for conventional steam trains and "high-speed straight air-control equipment" for use on streamlined trains. Automatic control of the electric brake may be used in combination with both systems. When used, the full capacity of electric braking is available, assisting the air brakes in slowing down and stopping the train (electric braking is effective at all speeds down to about five miles per hour). The arrangement is such that air pressure to the driver brake cylinders is suppressed when the electric brake is functioning normally.

Every effort has been made to provide the greatest flexibility possible in the control of the electric brake, both separately and in combination with air, so that full advantage can be taken of this new type of braking under all operating conditions.

Train Control. The locomotive is equipped with three separate train-control systems to conform to the different lines over which it will operate. A two-indication continuous-cab-signal system with two-speed control is provided for operation over the lines of the Chicago and North Western Railway. A two-indication continuous-cab-signal system with whistle and acknowledging feature is included for use on the lines of the Union Pacific Railroad. An intermittent magnetic inductive automatic stop system is provided for use on the Southern Pacific.

Comparative Costs

Although it is too early to make accurate comparisons of initial and operating costs between the steam-electric and other types of locomotives, a few approximations may be of interest. Under normal shop-production conditions, it is expected that steam-electric locomotives of this type can be built at a cost not more than twice that of a reciprocating steam locomotive, or about the cost of a Diesel-electric.

Fuel costs of the steam-electric unit are expected to be not more than 60 per cent of the fuel cost for a reciprocating steam locomotive and slightly less than the fuel cost for a Diesel-electric unit. Although the efficiency of the steam-electric is somewhat less than that of the Diesel-electric, the lower grade of fuel oil used is less expensive, thereby allowing the cost of fuel for the steam-electric to be slightly less than that for the Diesel-electric.

Other advantages of the steam-electric locomotive that have a direct bearing on the over-all cost are its high availability, ability to run long distances with short terminal layovers, low water consumption, and expected low maintenance cost. In addition, its uniform balanced drive and moderate axle loading tend to promote safety and decrease track maintenance.

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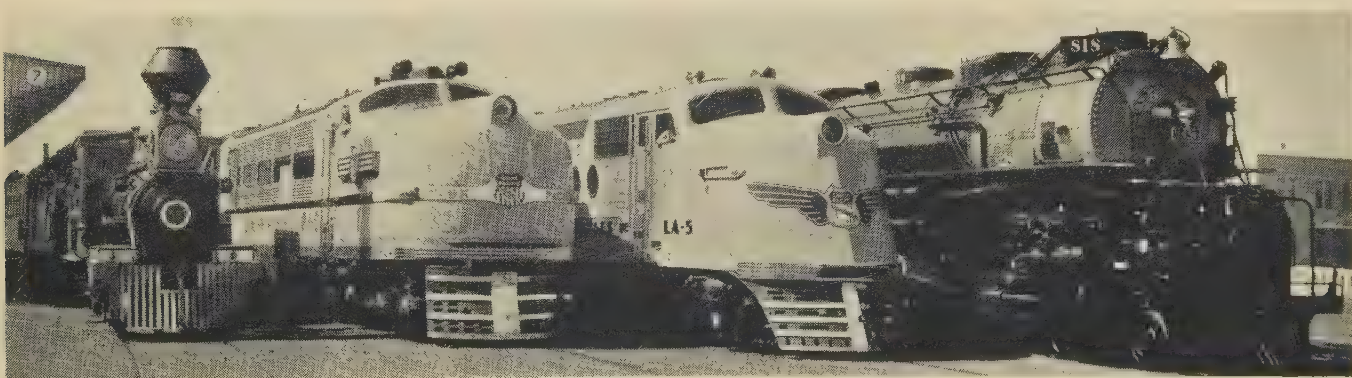

The old and the new; left to right: a wood-burning steam locomotive used in 1865 by the Union Pacific Railroad; the new 5,000-horsepower steam-electric locomotive; Diesel-electric locomotive of the crack passenger train "City of Los Angeles"; and at the extreme right a large modern reciprocating steam locomotive

Mechanical Demonstrator of Traveling Waves

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By means of the device described in this article, which simulates in a mechanical sense the electrical phenomena of traveling waves on power-transmission lines, various types of surges may be visualized and relations fundamental in transmission theory may be deduced.

COLLEGE PROFESSORS are invariably of the opinion that demonstration equipment, by visualizing to the observer the actual operation of the equipment, is of considerable aid to the understanding of the phenomenon involved. Analogies, by arguing from the known to the unknown, or from the familiar to the unfamiliar, are of additional assistance. It is frequently possible through the use of an analogy to illustrate a phenomenon visually that under other circumstances would be somewhat abstract. This is particularly true of mechanical analogies of electrical phenomena; one cannot see electromotive forces or currents, but can see the physical movement of mechanical bodies.

The simplest mechanical analogy, one with which almost everyone is familiar, consists of the simple spring, mass, and damping element which is used to simulate the electrical equivalent of capacitance, inductance, and resistance. These equivalents are illustrated in figure 1. The force required to stretch a spring is proportional to the displacement; but since the displacement is the integral of the instantaneous velocity, v, the force can be expressed by $K\int v dt$. Similarly, the force exerted by the inertia of a mass is proportional to the acceleration and can be expressed by $M\ (dv/dt)$. A pure damping element must be so constructed that the force exerted by it is proportional to the velocity $K_d v$. Turning to the electrical system one finds similar relations. The voltage drops across a capacitor, inductor, and resistor are equal, respectively, to $(1/C) \int idt$, $L(di/dt)$, and Ri. By comparing these expressions it can be seen that if capacitor, inductor, and resistor of the electrical system be replaced by spring, mass, and damping element of the mechanical system the forces across the mechanical elements are the same functions of v as the voltage drops across the corresponding elements of the electrical system are of i. The third column depicts the corresponding counterparts of the mechanical system for rotary motion.

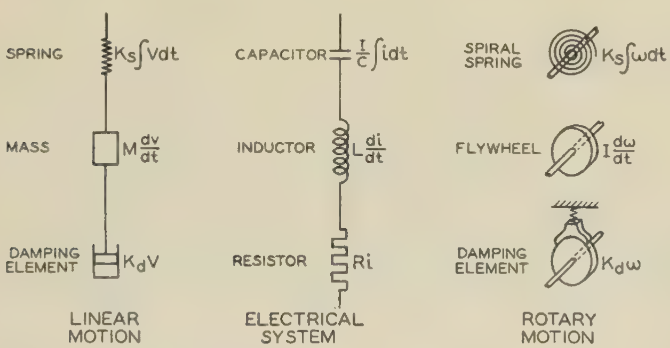

Figure 1. Correspondence between electrical and mechanical systems

A transmission line can be conceived as being made up of elements of series resistance and reactance with capacitance in shunt. The effect of series resistance is to produce both attenuation and distortion of the wave. For several span lengths, however, both these effects are negligible, and in this discussion a resistanceless line is premised.

A resistanceless line can be simulated in the mechanical analogue by means of elements of the type shown in figure 2. Each element consists of an aluminum arm, mounted at its center of gravity, upon two pivot bearings of hardened steel. Near the point of mounting, a flat steel spring is fastened securely. The free end of the spring is secured to the end of the adjacent arm. Fifty-six such arms mounted in the manner described are shown in figure 3. This constitutes the main portion of the demonstrating device. In each element the mass of the arm corresponds to the inductance of the line and the spring to the shunt capacitance. The friction of the mounting has been kept to a minimum. The little friction that remains corresponds in the transmission line to shunt or leakage resistance. Apparatus of this general character is not new, as evidence the vertical mechanical wave machine which is in practically all physics laboratories and also the wave machines on demonstration at the Franklin Institute. It is believed, however, that this particular model lends itself better than others to the demonstration of the electrical problems discussed in this article.

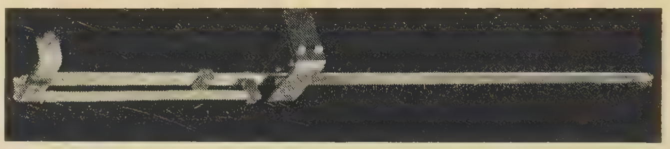

Figure 2. One element of wave demonstrator

For some of the demonstrations to be discussed it is necessary to simulate shunt-connected resistances on the transmission line. Referring to figure 1, it may be seen that these can be simulated by a device in which the force exerted is proportional to the velocity. For this purpose small single-phase squirrel-cage induction motors are utilized. These motors are excited by direct current

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instead of alternating current, the source being six dry cells. Because of the constant field, any motion of the rotor develops in the rotor an electromotive force that is proportional to the instantaneous value of the velocity. At the frequencies involved, or, stated more accurately, for the velocities involved, the inductive drop in the rotor is negligible so that the current in the rotor is determined purely by the electromotive force and the rotor resistance. The reaction of the rotor current with the magnetic field then produces a retarding force or torque proportional to the stator current and the instantaneous velocity of the rotor. This is just the characteristic required by the relations of figure 1. The effect of different resistances in the electrical system is obtained simply by varying the stator current. These elements, of which there are four, are mounted on a lower angle section as shown in figure 3. When desired they may be connected to the arms by means of the strings (figure 4) which transfer the rotary motion of the arms to that of the rotors of the motors. They have been placed on the lower bracket instead of directly on one of the arms for several reasons: First, the weight of the rotor is more than a delicate arm bearing would withstand; second, there would be insufficient space on one of the arms; third, the string connection permits amplification of the motion.

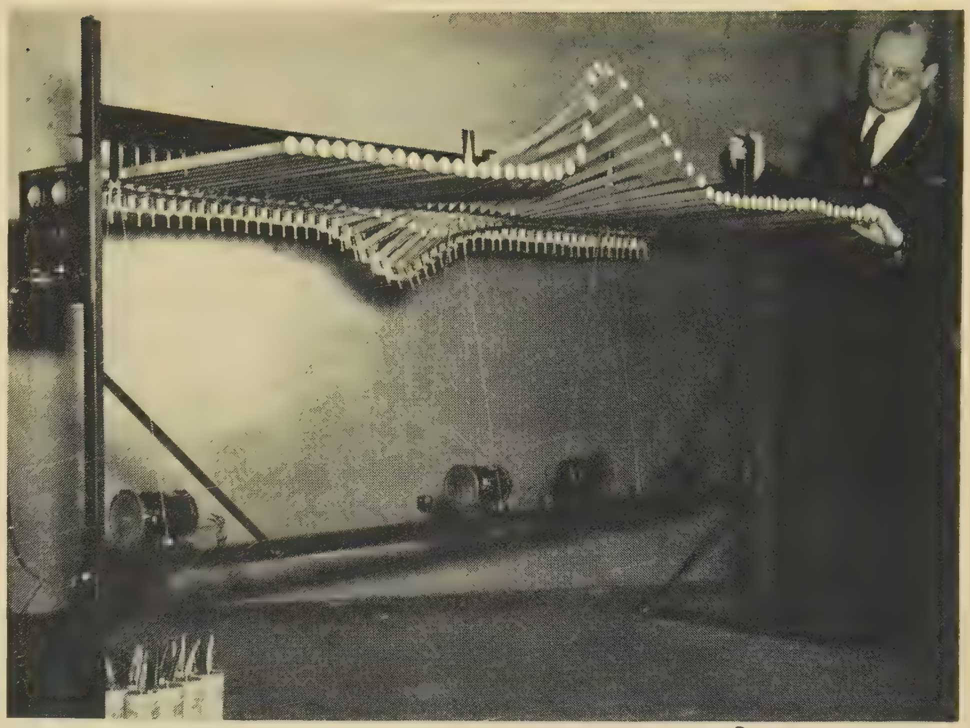


Figure 3. General view of wave demonstrator being operated by author

With the device just described it is possible to illustrate many of the phenomena associated with the problem of traveling waves, including reflections at transition points, effect of tower-footing resistance, and the like. Further, arguing from experiment, it is possible to derive most of the fundamental laws of traveling waves. In the absence of direct visual testimony in a written description, some of these experiments are shown by a succession of frames taken from a motion picture. Unless otherwise stated, the resistance elements are assumed to be disconnected from the line.

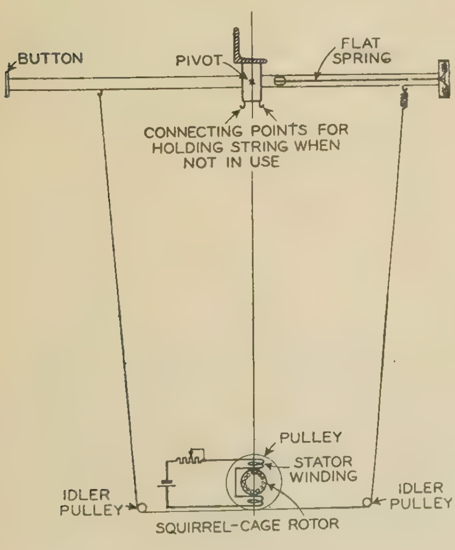


Figure 4. Schematic diagram of damping element which simulates shunt resistance

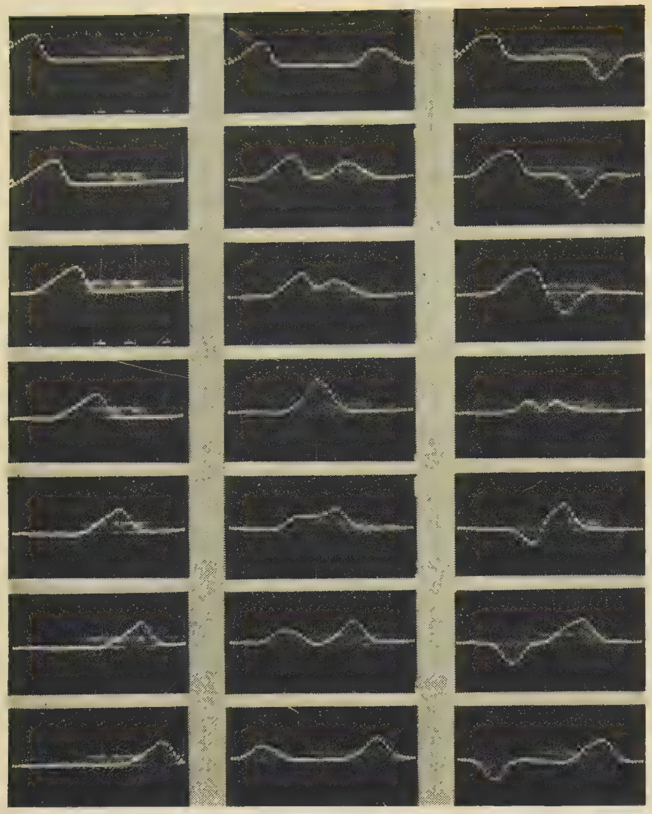
Simple Wave Motion

If this system is disturbed by moving the end element manually in a vertical direction, the motion is propagated along the row of arms in the form of a wave, the shape of the wave and its amplitude being maintained as the wave progresses along the line. The nature of the propagation is depicted in figure 5 which shows successive positions of the wave. This is true regardless of the shape of the wave impressed upon the device.

It is apparent that if the mass of each arm in the device is increased the motional response of an arm to the deflection of its spring will be slower. A disturbance then would be transmitted from arm to arm at a slower rate and the velocity of propagation of the wave would be slower. A similar result occurs in an electric line with distributed constants if the inductance (or mass) is increased. This relation is in accordance with the quantity $1/\sqrt{LC}$, which expresses the velocity of propagation of the wave in a line. By varying the mass of the arms and the stiffness of the springs this relation can be verified experimentally.

Waves Passing Through Each Other

The performance of two waves that reach a point from two different directions is interesting. Their action is



(a) (b)

Figure 5 (left). Simple wave motion

Figure 6 (a and b). Two waves passing through each other

(a) Two positive waves

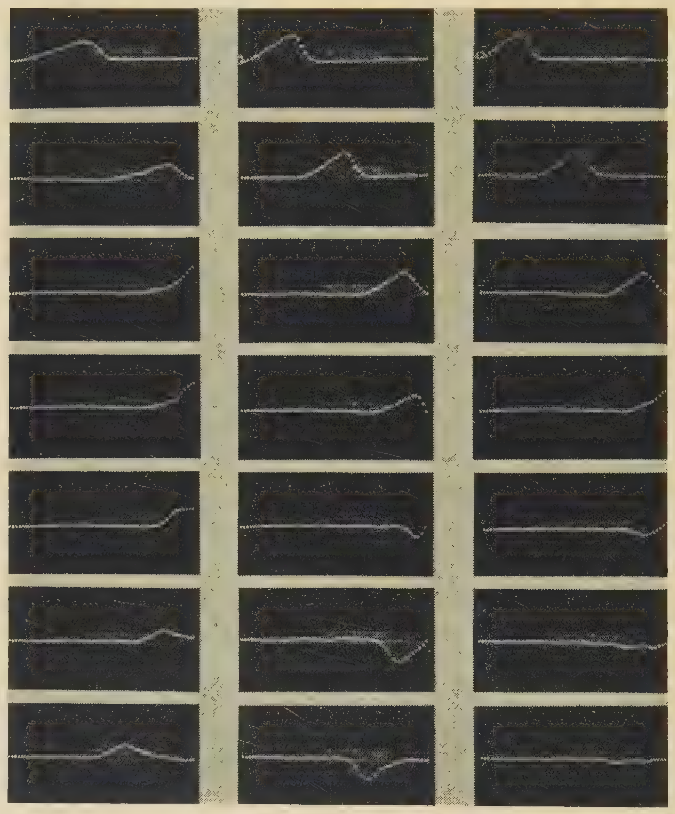
(b) One positive and one negative

shown in figure 6*a*. It may be seen that both waves pass through each other with unchanged amplitudes and wave forms. During the period of passage the amplitudes are additive. Figure 6*b* shows a similar phenomenon in which one of the waves is positive and the other negative.

Reflections at the Ends of Lines

There is perhaps no more important phenomenon in the theory of traveling waves than that of the reflections at the ends of lines. Consider first an open-circuited line. This corresponds in the mechanical analogue to the condition in which the end arm is permitted to swing freely. As shown in figure 7*a*, the reflected wave has the same shape and amplitude and also the same polarity as the oncoming wave. In addition, the maximum voltage at the end of the line is equal to twice the maximum value of the oncoming wave. Since the waves under discussion are voltage waves, then a short-circuited line can be represented by constraining the end arm from moving. This is easily accomplished by clamping the end arm in position. The result for this case is shown in figure 7*b*, where the reflected wave has the same shape and amplitude as the oncoming wave, but the opposite polarity.

A line terminated by a resistance is represented in the mechanical analogue by connecting one of the previously described damping elements to the end arm. When the current in the stator is small, that is, the damping is small, a high resistance is simulated and the reflected wave is of the same form and polarity as the oncoming wave, but the amplitude is smaller. When the current in the stator is large, the reflected wave has the same shape, opposite polarity, and smaller amplitude than the oncoming wave. By properly adjusting the stator current, or damping, a condition is attained for which there is no reflected wave (figure 7*c*). It follows then that for an actual transmission line there exists a particular critical resistance which when connected in shunt across the terminals at the end of the line results in no reflected wave when an oncoming wave strikes the end; the wave is completely absorbed. This condition is extremely interesting and from it several



(a) (b) (c)

Figure 7. Reflections at the end of a line

(a) Open end

(b) Short-circuited end

(c) Critical resistance across end

important relations can be deduced which are fundamental in transmission theory.

In figure 8 let the section AB represent a finite section of an infinitely long line extending from A to the right. A wave propagated from A would travel indefinitely to the right. The point B would be no different from any other point on the line and there would be no reflection of the wave at that point. If now the line at B were opened and a resistance having a critical value were connected

across the open end at B, then likewise there would be no reflection at B to an oncoming wave. This shunt resistance then must perform in all respects as the infinitely long line from B to the right. It is known that the current in the resistor must be proportional at any instant to the voltage across it; more specifically the current must be equal to e/R_c, where e is the instantaneous voltage and R_c is the value of the critical resistance. It follows, therefore, that in the infinitely long line a current must flow that is related at any instant to the voltage by the same relation. This is a fundamental of all traveling-wave theory—that a current wave of the same wave form attends all voltage waves. A particular name, the surge impedance of the line, and particular symbol, Z, have been given this critical resistance; it can be shown to equal $\sqrt{L/C}$, where L and C are the inductance and capacitance, respectively, per unit length of line. As can be seen from the experiment in which the resistance R_c is connected across the line, the direction of propagation of the wave in the line corresponds to that of the direction of current flow, that is, a positive voltage wave produces a positive current flow in the direction of propagation of the wave.

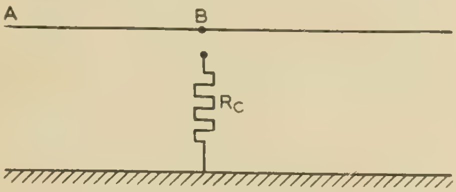


Figure 8. Diagram to prove that current wave of same shape accompanies voltage wave

With this conclusion it is possible to extend what has been proved here regarding wave theory. Assume a forward moving wave e_f. It will have associated with it a current wave i_f equal to e_f/Z. A backward moving wave e_b would have associated with it a current wave e_b/Z in which the positive sense of current flow is in the backward direction along the line. For analytical use it is rather inconvenient to have different positive senses of current flow, so if the positive sense for both current waves is chosen as the direction of the forward wave,

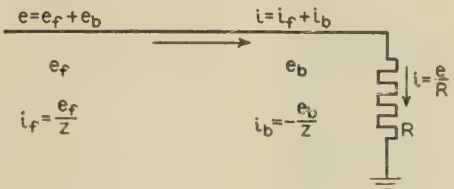


Figure 9. Schematic diagram of transmission line terminated by a shunt resistance R

$$i_f = \frac{e_f}{Z} \tag{1}$$

and

$$i_b = -\frac{e_b}{Z} \tag{2}$$

In general two waves of this nature can exist simultaneously, as was illustrated in several of the experiments, the most outstanding in this regard being the one in which two waves traveling in opposite directions passed through each other.

If a line is terminated by a resistance R, both an oncoming and a reflected wave appear. If these are given the designation shown in figure 9, then at the end of the line the total current, i, is equal to

$$i = i_f + i_b = \frac{e_f}{Z} - \frac{e_b}{Z} \tag{3}$$

Similarly, the total voltage at the end of the line is

$$e = e_f + e_b \tag{4}$$

But this voltage is also equal to the drop across the resistance, and since the total current must flow through the resistance

$$e_f + e_b = Ri \tag{5}$$

Substituting from equation 3,

$$e_f + e_b = R\left(\frac{e_f}{Z} - \frac{e_b}{Z}\right) \tag{6}$$

Solving this equation,

$$e_b = \frac{R - Z}{R + Z} e_f \tag{7}$$

This result has been obtained without recourse to any mathematics higher than just simple algebra. By means of this equation the experiments just performed for open-ended lines, short-circuited lines, and other conditions can be checked.

Power loading of an a-c line must be accompanied by a phase displacement between the voltages at the two ends of the line. The truth of this statement can be demonstrated best by considering the performance of the mechanical analogue loaded by its critical damping element when a continuous alternating disturbance (alternating voltage) is applied at the sending end. Because of the absence of reflections the waves continue to travel along the line without distortion at their natural speed. This is shown in figure 10. The performance should be independent of the frequency except that the waves would be crowded closer together at the higher frequencies. In an actual line the distance between nodes is equal to the distance the wave can move in one cycle. Thus for a 60-cycle wave the distance between nodes, or the wave length, is equal to the velocity of light (186,000 miles per second) divided by 60, or 3,100 miles. In other words, a 3,100-mile line would have a phase displacement of 360 degrees. Shorter lines would have phase displacements in proportion. A 200-mile line, for example, would have a phase displacement of (200/3,100) × 360 or 23 degrees. For larger loads, that is, smaller values of terminating resistance than the critical value premised,

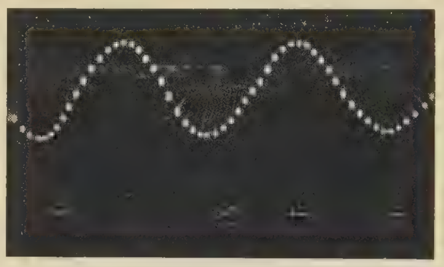
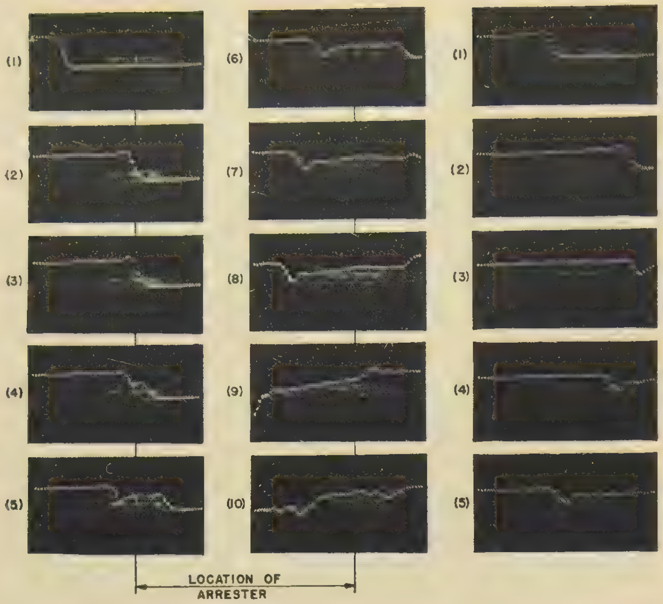


Figure 10. Voltage distribution with sustained alternating potential at sending end of a line terminated by a resistance having the critical value



(*a*) (*b*)

Figure 11. Operation of a lightning arrester in limiting the voltage on a transmission line

(*a*) Arrester at some distance from end of line

(*b*) Arrester at end of line

this angle is greater, and for smaller loads, that is, larger resistances, it is smaller. This raises a point that has given some persons considerable trouble. It is frequently argued that, since electricity travels with the speed of light, at no load the phase displacement between the voltages at the two ends of the line must be that corresponding to the time it takes light to travel the length of the line; that is, for a 200-mile line the phase angle must be 23 degrees. This argument neglects entirely the reflections at the ends of the line. It has just been demonstrated that these can be neglected only when they are zero, that is, when the critical damping resistance is connected in shunt across the terminals.

Lightning Arresters

Lightning arresters frequently are used for the protection of transformers. It is important that they be located as close as possible to the equipment to be protected. The truth of this statement can be demonstrated on the mechanical demonstrator in which the lightning arrester is represented by means of a fixed rod which limits the travel of the arm at the location corresponding to that of the arrester. Electrically this corresponds to an ideal arrester for which the voltage is limited to a constant value regardless of the current flow. In other words, the volt-ampere characteristic of this ideal arrester is one in which the voltage is constant regardless of the current. The operation of this device when the arrester is located some distance from the end of the line is shown in figure 11*a*. It may be seen that as a wave approaches the arrester the arrester limits the voltage at that point and permits a flat-top voltage wave equal to arrester voltage to continue beyond the arrester. However, at the end of the line where the transformer to be protected might be located reflection occurs which raises the voltage to twice arrester voltage. This voltage will continue at this value until enough time has elapsed for a wave to be propagated from the end of the line to the arrester and back again. At the end of this time the negatively reflected wave from the arrester reduces the transformer voltage to arrester voltage. While in this case a very steep wave form was premised, a similar result can be shown to apply for waves less steep. If the wave front has a constant slope, it can be shown that the maximum transformer voltage is equal to

$$e_a + 2\frac{de}{dt}\frac{D}{1,000}$$

where e_a is the arrester voltage, de/dt is the slope of the oncoming surge in volts per microsecond, and D is the distance in feet between arrester and transformer.

If, however, the arrester is located at the end of the line it will not offer adequate protection to a transformer that is located out on the line too far. This likewise can be demonstrated on the mechanical device as shown in figure 11*b*. If the transformer is located out on the line too far the voltage across it will not be influenced until the negative reflected wave from the arrester has had an opportunity to reach the transformer. For a flat-top wave the transformer then would have a very high voltage applied to it for a time equal to the time required for a voltage wave to propagate from the transformer to the arrester and return.

Induced Lightning Stroke

Surges on transmission lines due to lightning may originate in either of two ways, namely, induced surges or direct strokes. Induced surges are those arising from strokes to other objects in the vicinity of the line, whereas direct strokes are those in which the lighting stroke itself or a side streamer strikes the line. The mechanism for induced strokes is somewhat as follows. The stroke usually originates at the cloud and propagates earthward at a relatively low speed as compared with that of light. During this process negative charge is lowered from the cloud into an immense antenna-like system of leaders in the air. This process may take a time of the order of 10,000 microseconds. As the downward leader strikes the earth a very brilliant leader is observed to travel upward. The currents associated with this upward leader are of the order of 10,000 to 150,000 amperes. These very large currents result because the same charges that had been lowered during the initial slow process in a time of about 10,000 microseconds are now discharged in the much shorter

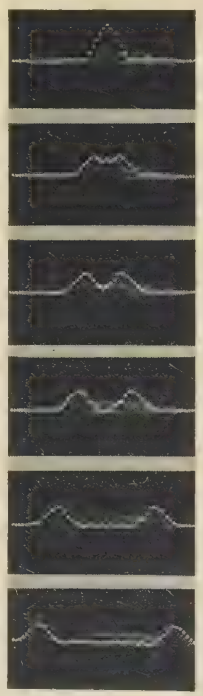


Figure 12. Breakdown of standing wave into two parts

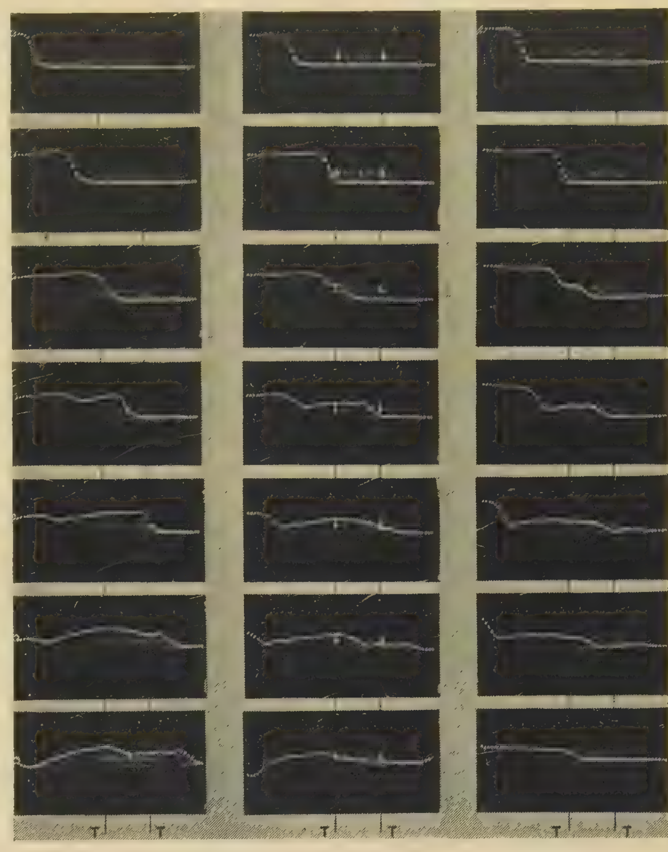
time of the order of 50 to 100 microseconds. While the charges are being lowered, the transmission-line conductors tend to attain a potential that is dependent upon their position. The principal contribution to this potential is that due to electrostatic effects. While these phenomena were considered very important in the early investigations of lightning, subsequent calculations indicate that they were overemphasized, because the mechanism is much slower than had originally been supposed.

In addition to the potentials that are produced by the lowering of the cloud charge there is also the very interesting phenomenon that since these fields are not produced instantaneously but require a finite time, part of the charge induced and the associated voltage produced can leak off along the transmission line. This phenomenon can be demonstrated in part by the wave demonstrator. Consider a wave of the form shown in the upper frame of figure 12. If this voltage is produced by an induced charge upon the transmission line it will exist as shown so long as the charge distribution remains as postulated. However, these charges are free to leak along the line and what happens is that the wave is broken up into two equal components, one traveling to the left and one to the right, the total voltage at any instant being equal to the sum of the two waves.

Direct Strokes

With the knowledge that a lightning stroke may have a potential of 10,000,000 to 20,000,000 volts and the crest value of the 60-cycle flashover of 12 insulators, the number that might be used on a 110-kv line, is only 700,000 volts effective, the question naturally might be raised as to how it is possible to protect such a string of insulators from flashing over. The answer lies primarily in the use of ground wires. For direct-stroke protection they must be so located as to insure interception of the stroke. This assumption is fundamental to the theory. For this purpose they must be located well above and not in too far with reference to the line conductors—a condition in direct conflict with the induced-stroke theory which required that the ground wires be located as close to the conductors as possible in order to increase the coupling. In the induced-stroke theory coupling is of prime importance, but in the direct-stroke theory it is relegated to secondary importance by the necessity of insuring that the stroke hits the ground wire.

Starting with the premise that the ground wire is struck, use can be made of the wave demonstrator to show how the voltage on the ground wire is reduced below that of the stroke voltage. Consider first the case shown in figure 13 in which lightning strikes the ground wire at the tower top. It has become generally accepted that after striking a grounded object the lightning channel might be regarded as any other conductor. While this is not strictly permissible it is sufficiently close to actuality for the present purpose. In addition, a further questionable assumption of the negligibility of the tower surge impedance will be made. Only the surge impedance of the ground wires and the tower-footing resistances will be considered. Upon striking the tower the surge divides between the two ground wires and the footing resistance of the stricken tower. The surge impedance of the lightning channel has been variously estimated as from 200 to 600 ohms and the surge impedance of a ground wire as about 400 ohms. Because of the symmetry of the circuit, it is permissible to consider one side of the line folded over onto the other side. The impedance of the two paralleled ground wires then would be 200 ohms and the impedance of each of the footing resistances, except that of the struck tower, would be one-half the single footing resistances. If the stroke impedance is chosen as 200 ohms, a circuit is obtained which can be



(a) (b) (c)

Figure 14. Potential of ground wire when lightning stroke occurs at a tower top

(a) High footing resistance
(b) Medium footing resistance
(c) Low footing resistance

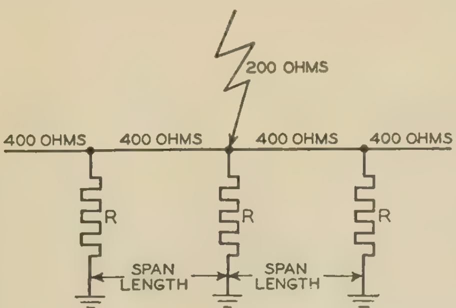


Figure 13. Schematic diagram of circuit when lightning stroke occurs at tower top

represented on the demonstrator. In figure 14 the portion of the demonstrator to the left of the left-hand "T" represents the lightning channel and the portion to the right, the ground wire. At each of the "T's," which represent towers, a damping element is connected to simulate the footing resistances. These elements can be varied to illustrate the effect of different footing resistances.

Figure 14*a* shows clearly how the potential of the first tower top varies when the damping elements are adjusted to represent high tower-footing resistances. It may be observed that the potential remains quite high with respect to the oncoming wave. There is little diminution in its magnitude. Figure 14*b* represents the case for which the footing resistances are smaller. The tower potential is much smaller and it can be observed that after the surge has traveled to the second tower a negative wave is reflected and reduces the potential at the first tower still more. Figure 14*c* shows the phenomenon when the footing resistances are reduced still further. For this case the tower potential is reduced to a very low value. It is important to note that not only is the magnitude of the potential reduced but also the time during which the peak exists is reduced.

In the usual mechanical analogies used to represent transmission lines, voltage is represented by force (or torque) and current by velocity. In this case a rigorous relationship exists for all conditions; in a forward moving wave torque is proportional to the negative of velocity and in a backward moving wave proportional to the velocity; reflections at the ends of lines are correct for resistors, capacitors, or inductors. Visual evidence of the torque is offered by the instantaneous slope. It is difficult, however, as a demonstration device to try to follow visually such variations as a slope or velocity. However, since the displacement is the time integral of velocity or the space integral of slope, the displacement can be used in certain cases to simulate voltage waves. This is permissible when the discontinuities involve resistors only. The truth of this statement may be evident from the fact that the first derivative of the reflected wave is proportional to the first derivative of the oncoming wave and therefore their integrals, which are the waves themselves expressed as displacements, are also proportional. With discontinuities involving capacitors and inductors, the proper similitudes exist for the velocities and slopes of the oncoming and reflected waves but not for their integrals.

Simplified Computation of Voltage Regulation

With Four-Winding Transformers

R. D. EVANS
MEMBER AIEE

COMPUTATIONS of voltage regulation ordinarily are based on the use of an equivalent circuit for the four-winding transformer, using either a six-branch network, or preferably the eight-branch network described by Starr.[1] Determination of the equivalent circuit—a tedious analytical task—appears to be unnecessary, however. As a simpler alternative for determining voltage regulation with load on three windings and the fourth winding acting as a source, the necessary constants may be obtained directly from the usual two-terminal impedances.

For example, assume a four-winding transformer with loads, impedances, and terminals designated as shown in figure 1. The two-terminal impedances are assumed to be available from calculations or tests, and to be reduced to a common kilovolt-ampere and voltage base. The voltage drops to terminals H, M, and L may be computed from the following equations:

$$E_H = E_S - D_{HH}I_H - D_{HM}I_M - D_{HL}I_L \quad (1)$$

$$E_M = E_S - D_{MH}I_H - D_{MM}I_M - D_{ML}I_L \quad (2)$$

$$E_L = E_S - D_{LH}I_H - D_{LM}I_M - D_{LL}I_L \quad (3)$$

in which D_{HH}, D_{HM}, D_{HL}, D_{MH}, D_{MM}, D_{ML}, D_{LH}, D_{LM}, and D_{LL} are the self- and mutual-impedance voltage-drop constants of the network. These constants are obtained by considering unit load at the terminal indicated by the second subscript and determining the voltage drop measured from the source S to the terminal indicated by the first subscript.[2] Thus D_{HH}, D_{MM}, and D_{LL} are respectively the self-impedances of the transformer from terminal S to the terminals H, M, and L, respectively. The other symbols indicate the mutual voltage-drop constants.

The values of these voltage-drop constants in terms of the two-terminal impedances are as follows:

$$D_{HH} = Z_{SH} \quad (4)$$

$$D_{MM} = Z_{SM} \quad (5)$$

$$D_{LL} = Z_{SL} \quad (6)$$

$$D_{HM} = D_{MH} = \frac{Z_{SH} + Z_{SM} - Z_{HM}}{2} \quad (7)$$

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1. For all numbered references, see list at the end of the article.

$$D_{HL} = D_{LH} = \frac{Z_{SH} + Z_{SL} - Z_{HL}}{2} \qquad (8)$$

$$D_{ML} = D_{LM} = \frac{Z_{SL} + Z_{SM} - Z_{LM}}{2} \qquad (9)$$

The derivation of the formulas for the voltage-drop constants may now be considered. The values for D_{HH}, D_{MM}, and D_{LL} are obviously the self-impedances between

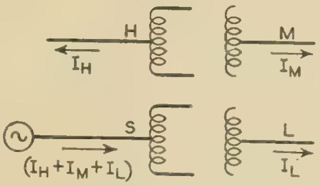

Figure 1. Schematic diagram of four-winding transformer two-terminal impedances Z_{SH}, Z_{SM}, Z_{SL}, Z_{HM}, Z_{HL}, and Z_{ML}

the source and terminals H, M, and L, respectively. For the determination of the mutual voltage-drop constants it is convenient to use an equivalent circuit such as Starr's form, as shown in figure 2. It is not necessary to determine the values of the branch impedances, a, b, c, d, e, and f, but merely to assume that the transformer may be represented in this manner. Remembering the definition of the voltage-drop constant as the impedance drop caused by unit current at the terminal indicated by the second subscript and determining the drop from the source S to the terminal indicated by the first subscript, one may write the following equations by inspection.

For unit load drawn from terminal H and supplied from S, the voltage drop from source to M is:

$$D_{HM} = D_{MH} = d + (e+f)\frac{f}{2(e+f)} = d + \frac{f}{2} \qquad (10)$$

Similarly,

$$D_{HL} = D_{LH} = d + \frac{ef}{2(e+f)} \qquad (11)$$

$$D_{ML} = D_{LM} = d + \frac{e}{2} \qquad (12)$$

The values of $\left(d + \frac{f}{2}\right)$, $\left(d + \frac{ef}{2(e+f)}\right)$, and $\left(d + \frac{e}{2}\right)$ may be expressed in terms of the two-terminal impedances by the following method. The impedances between terminals of the equivalent network may be written by inspection and equated to the corresponding two-terminal impedances with the following results:

$$a + \frac{e(2f+e)}{2(e+f)} + b = Z_{MH} \qquad (13)$$

$$a + \frac{e+f}{2} + c = Z_{HL} \qquad (14)$$

$$a + \frac{f(2e+f)}{2(e+f)} + d = Z_{SH} \qquad (15)$$

$$b + \frac{f(2e+f)}{2(e+f)} + c = Z_{ML} \qquad (16)$$

$$b + \frac{e+f}{2} + d = Z_{SM} \qquad (17)$$

$$c + \frac{e(2f+e)}{2(e+f)} + d = Z_{SL} \qquad (18)$$

By solving for a from equation 15, b from equation 17, and c from equation 18, and substituting in the remaining equations:

$$d + \frac{f}{2} = \frac{Z_{SH} + Z_{SM} - Z_{HM}}{2} = D_{HM} \qquad (19)$$

$$d + \frac{ef}{2(e+f)} = \frac{Z_{SH} + Z_{SL} - Z_{HL}}{2} = D_{HL} \qquad (20)$$

$$d + \frac{e}{2} = \frac{Z_{SM} + Z_{SL} - Z_{LM}}{2} = D_{ML} \qquad (21)$$

This verifies the relations given in equations 7 and 9.

Perhaps it should be pointed out that voltage-regulation

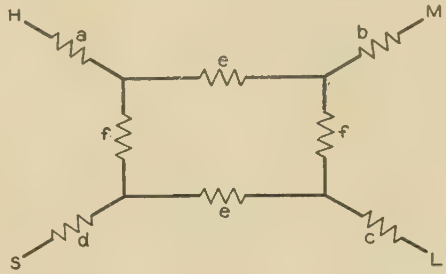

Figure 2. Equivalent circuit of four-winding transformer

problems are frequently stated in terms of kilovolt-amperes and power factor instead of load currents. For such cases the method just outlined may be used by adjusting the assumed currents in accordance with actual voltages at various terminals.

References

1. An Equivalent Circuit for the Four-Winding Transformer, F. M. Starr. *General Electric Review*, March 1933, pages 150–7.

2. Symmetrical Components, C. F. Wagner and R. D. Evans. McGraw-Hill Book Company, New York, N. Y., 1933, chapter 12.

Service Voltages for Lighting

The General Electric Company's annual analysis of population reported as being served at various lighting voltages shows a continued shift toward 120 volts, with decreases in both the 115- and the 110-volt percentages. The percentage of population receiving lighting service at 125 and 130 volts is almost negligible (actually less than one-tenth of one per cent) and shows no sign of increasing. The trend is as shown in the following table.

Per Cent of United States Population in Areas Supplied at Different Voltages—100–130 Volt Range

Voltage	1923	1928	1933	1937	1938
110	36.3	15.9	5.2	1.8	1.4
115	40.9	61.6	61.7	52.1	49.5
120	19.4	22.4	33.0	46.0	49.0
All others	3.4	0.1	0.1	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0
Average voltage first three items only	114.1	115.3	116.4	117.2	117.4

Why So Few Famous Engineers Today?

IN A thought-provoking article published in the August 17, 1939, issue of *Engineering News Record*, Farley Gannett asks why so few engineers of today have obtained fame comparable to that of many engineers of past decades and puts forward several of the most plausible explanations that have been suggested to him. Excerpts from the article are given in the following paragraphs.

The deaths of Harrison P. Eddy, Hugh L. Cooper, and Guglielmo Marconi left notable vacancies in the fast dwindling ranks of the world's famous engineers. Within a decade Allen Hazen, General Goethals, Leonard Metcalf, Thomas Edison, James H. Fuertes, Frederick P. Stearns, Waldo Smith, Charles P. Steinmetz, M. I. Pupin, John R. Freeman, and others have departed, leaving monuments in waterworks, bridges, sanitary and electrical engineering works. It was through these men that engineering developed in the last two or three decades, and it was by reason of men like them and Rudolph Hering, Alfred Noble, the elder Fuertes, Waring, George Westinghouse, Desmond Fitzgerald, Barclay Parsons, Roebling, Eads, and others that engineering became an important and respected profession in the United States; their names became and have remained familiar and honored among members of their profession, some of them also to the general public.

A few engineers of note are still with us, such as Ralph Modjeski, John F. Stevens, John Hays Hammond, Herbert Hoover, and Arthur Morgan. We all know these men by reputation. There are not many that could be added to this list today. Ten years ago there were a score or more of names well known in engineering for years; only a few have made their reputations recently. The list of great ones has been steadily declining, and no recruits seem to be filling the depleting ranks.

There are many reasons why an engineer becomes well known; it may be ability, it may be luck, it may be character, it may be salesmanship or ambition or perseverance or any number of other things or a combination of several. Without some ability it would be hard to think of an engineer becoming famous, but a combination of ability and a decided character would be a great help. Add salesmanship or showmanship and a little luck and a lot of perseverance, and maybe there you have it, but there must be daring and courage because these make for human interest, and there is seldom fame without human interest.

Why were the men named above widely known? Why are their names and their deeds living after they are gone? Did these men achieve fame because they were among the ablest of engineers, or were some of them mediocre engineers who had something else that made them prominent among others, that caused them to be remembered and their names to become familiar to succeeding generations of engineers?

The consensus among men with whom I have talked seems to be that it requires a pioneer to make a name for himself, and they seem to think that the possibilities for pioneering in engineering have ceased. But have they? Will pioneering ever really cease? New developments, changes in old, involve pioneering. There are so many things being done on a far larger scale that it is hard to tell what is pioneering and what is not, but it is just as unfair to say that there is no more pioneering possible in engineering today and in the future as it would have been to say it 50 years ago.

Another answer given me was that much of the great work today that would otherwise make men famous is being done by the government and that names and individuals are submerged in government work. Nevertheless, there are hundreds and perhaps thousands of engineers in private practice today who are not doing government work and none are even projecting their heads above the horizon. Another suggestion is that engineers who are not working for the government are mostly working for corporations and that corporate employment eliminates the possibility of a man's making a name for himself. He may make his corporation famous, but not himself. Steinmetz worked for a great corporation and yet he achieved fame.

Another suggestion is that for every engineer graduated from engineering schools 50 years ago there are from 10 to 100 being graduated now; that it is harder to emerge from a large field than it is from a small one. Also, where competition is so strenuous as it is today and has been for 20 years, one gets much less opportunity for accomplishing great results.

The engineering profession is being used for greater things today than ever before in this or any other country's history. Why are not personalities being developed from these great works, why are not engineers being made famous thereby? This should be a time not only of greatness of our profession but for the individuals in it.

There is an old saying that you can't keep a good man down, and maybe that is what it is—that there aren't really good men developing in the profession today. And by a good man, I mean not only intelligent, educated, trained, and experienced, but I mean a man of character, energy, and, above all, enthusiasm and a certain amount of showmanship. Such a man should be able to rise from those around him to get above the surface and have his name resounding from the housetops whether he works for Uncle Sam, for a great corporation or for himself.

In an editorial commenting on this article the New York *Sun* on August 28, 1939, called attention to a statement made recently by President Harvey N. Davis of Stevens Institute of Technology to the effect that life in the 20th century has been profoundly changed by engineering, and that the social and economic significance of the profession will increase. "In short," the editorial concluded, "engineering itself may become more 'famous' than any of the great personalities in its past have made it." Perhaps some readers of ELECTRICAL ENGINEERING will be stimulated to reflection on this subject; contributions to the "Letters to the Editor" columns are invited.

Effects of Technology on Our Social Thinking

ROBERT W. KING
MEMBER AIEE

The many and varied successes in technology have inspired in the minds of millions unskilled in technological methods the belief that such methods are directly applicable to social problems. The engineer should be the first to recognize the danger in this misconception and should do what he can to educate and warn the lay public that principles applicable to his inanimate problems cannot be applied directly in the domain of social phenomena.

EMERSON said "To be great is to be misunderstood." Perhaps the time has come when engineering has attained to a degree of eminence that causes it to be misunderstood. I do not mean, of course, that it is misunderstood by those "skilled in the art," but rather by the great lay public. This nontechnical opinion does not take any derogatory form—rather, it is overflattering; and herein may lie certain dangers.

Technology in its applications has been so fruitful that it has certainly aroused the popular imagination. With what powers and potentialities the nontechnical mind in general clothes technology it is impossible to determine. But evidence is not lacking that in many respects people have come to expect more than can be delivered. Nature, in rewarding research efforts with so rapid a disclosure concerning the properties of materials, tends to distort the perspective of the layman. In bringing not only the comforts of life, but many of its luxuries as well, virtually within the reach of every one, the modern machine age has come so near realizing age-old dreams of plenty that mass patience breaks down even at the prospect of small delays in progress toward greater material welfare. An economic depression is not a new phenomenon. Nor was it so long ago that hard times meant not only misery but virtual starvation for multitudes. Today, even in depressions, our poorest classes are perhaps better off than were most of our forebears 200 years ago in times then considered prosperous.

As engineers we have quite properly emphasized the importance of efficiency—each improvement in our prime movers being measured in terms of thermal and mechanical efficiency—until the world generally has taken up the chant, demanding now that the affairs of state be subjected to the criterion of efficiency. The engineer should be the first to recognize that there is danger here of misusing a good idea. But, further, he should do what he can to educate and warn the lay public that principles applicable to his inanimate problems cannot safely be carried over, without careful scrutiny, to the domain of social phenomena. To be sure, there are such things as an efficient government, an efficient banking system, an efficient educational institution. But the definition of what we mean by the word "efficiency" when used in this sense is far more complex and difficult to state than the precise meaning we have in mind when we speak of the efficiency of a mechanical device. Among other things, we must temper our technological desire for efficiency with the justifiable demands of individual liberty. The mechanically efficient state is symbolized by the military type of organization. It has its uses, but I am sure it is not a satisfactory substitute for a democratic political structure. Our present democratic forms express many centuries of evolution and it is difficult to believe that we must now establish arbitrary and despotic forms of governmental administration in order to assimilate the benefits that are potential in technology.

Closely connected with the engineer's concept of efficiency is that of planning. No one would undertake to build a power house, a railroad, or a factory without a carefully worked-out plan. In the minds of millions unskilled in the methods of engineering, the engineer's success in planning his quantitative undertakings has inspired the belief that planning can be equally effective when applied to affairs of state. This belief might perhaps be classed as faith in the formula and in the machine. We expect an educational formula to make us wise and we expect a social machine to make us prosperous. National planning and planned economy are now popular catchwords. Why tolerate unbalance and maladjustment in matters involving national welfare when we have succeeded in eliminating them from the generating station and assembly line?

National Planning Leads to Dictatorship

This argument is appealing—insidiously so—particularly to those who are not overly familiar with the true nature of the engineer's work and who do not detect the fundamental differences between his problems and those of administration and government. In brief, the trouble is that the social state is a collection of diverse groups with individual interests and ambitions. We see in Europe some attempts to surmount this situation. Whether these European governments label themselves Fascist or Communist, the essence of their political creed is that the individual exists only for the state. This is frequently referred to as the beehive type of social structure. Under one condition, this sort of regimentation, if one likes it, will get him out of a lot of trouble by cutting a sort of Gordian knot. The one condition is that the leadership of the regimented state be infallible. But if we do not

Based upon an address contributed to the symposium on "The Social Significance of Engineering" held October 26, 1938, at Lehigh University, Bethlehem, Pa.

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like to have our lives entirely ordered for us, we must recognize at the outset that the business of planning, when once introduced into the affairs of state, permits of no moderation. It is not a mere matter of chance that the three planned economies of Europe are harsh dictatorships. It cannot be otherwise. To plan without having a dictator to enforce execution would be as idle as for the engineer to build his ships of cardboard and his transmission lines of string. Each and every national plan, no matter how wisely and beneficially conceived, is bound to curtail the activities of certain groups while it enlarges those of other groups. Spontaneous resistance of affected groups is therefore inevitable, and such resistance and refusal to co-operate, unless quelled, must frustrate attainment of the goal conceived in the plan.

National planning lands us, therefore, at one jump in the hands of dictatorship. History speaks very plainly on this point. National planning is not an idea characteristic alone of our day, although it may well be that the engineer's success has been the means of resuscitating into a present menace what for a century and a half has been regarded as discredited theory. Modern advocates are boosting for a system which earlier periods were greatly relieved to be rid of. Rigid governmental control characterized the industry of England in the days of mercantilism immediately preceding the advent of the industrial revolution. Nor was England unique. According to Eli F. Heckscher (see Walter Lippmann's "The Good Society") there was a tightly drawn system of regulations whereby Colbert, the minister of Louis XIV, sought in his day to codify industrial practices. For the period 1666 to 1730, the regulations relating to the textile industry alone ran to over 2,200 pages, and he estimates "that the economic measures taken in this connection cost the lives of some 16,000 persons, partly through executions and partly through armed affrays."

Before leaving this general subject of what we might call the indirect or inferential effects of technology upon our social thinking, I feel that one other aspect is deserving of emphasis. It is one that naturally appeals more strongly to those engineers who are engaged in industrial practices than to those who have followed the academic side. At the outset I mentioned the rapidity with which the scientist and the engineer have developed new comforts and conveniences, and that this may have given rise to impatience on the part of those who believe that, like technical improvements, social changes and benefits should come out of some laboratory for political invention more quickly than they do.

Technological Events Cast Their Shadows Before

But rapidity of development in technology is much more apparent than real. Only those who see behind the scenes realize how many years frequently go into the developmental stage of some apparently simple product. As an example, I might refer to the telephone handset which which you are all familiar. Superficially it consists simply of a handle to which is attached a telephone microphone at one end and a receiver at the other. Actually it took years to develop, and herein lies the explanation of why it was not introduced in the United States much earlier. American telephone engineers were not at all satisfied with the early European handset, and to have adopted it would have seriously degraded the standard of telephone transmission established in this country. The accusation was occasionally heard during those early years that telephone engineers were indifferent to the desires and convenience of the American public, but this was farthest from the case. As a matter of fact, even after laboratory studies and a long program of development, it was not until upward of a million handsets had been manufactured and had been in service for from one to three years that a final design could be drawn up which it was confidently known would stand up in everyday service. The early handsets for the most part long ago vanished from service, but as a trial installation they were invaluable.

This I mention as just a simple illustration of the fact that the sort of thing which seems to the outsider to occur quickly is, in reality, a process of painstakingly feeling one's way. It is a fact that every line of industry verifies. Most emphatically is it true that coming technological events cast their shadows before, and usually years before.

Social Changes Should Be Inaugurated Slowly

Now the moral, as regards our present discussion, will be apparent. Social changes, even more than industrial changes must be inaugurated slowly if they are not seriously to upset such balance as our social machine attains. Moreover, the problem of inaugurating changes is greatly complicated by the lack of any laboratory for research and any facilities for conducting trial installations under suitable controls. What would the engineer do in his own domain under such circumstances? He would deliberate, study carefully, and scrutinize very closely such chances for experimentation as do arise. And I suggest that this is the advice which the technological fraternity at every opportunity should bring to the attention of the lay public.

For my part I like to think of this analogy, and to those who are familiar with thermodynamics it may also appeal. In social reforms we ought to strive to bring about changes by a sort of infinitesimal process. This may sound a bit idealistic, but like the thermodynamic counterpart, it gives definite limits which our practical operations can approach. Consider this example: At the telephone laboratories new ideas are being turned out with no end of enthusiasm, and yet the telephone business as a whole is not pulled and hauled and periodically upheaved as a result of new discoveries and inventions. The process of assimilation takes place smoothly and quietly—in fact, it forms an excellent practical illustration of what in thermodynamics is called a reversible change, where the exchange is not of quantities of heat, but of new ideas and new methods for old.

In a large social group such an objective is manifestly difficult to attain. A system of checks and balances is vitally essential; and underlying it there must be a popular

understanding that social evolution, to be effective, cannot come about as the result of the rapid administration of charges of legislative dynamite which convulse the national organism. In such an educational program engineers might well lead the way since they, perhaps more than the members of any other profession, realize the practical importance of slow and balanced development.

Perhaps the economist has overworked the expression "in the long run." More likely, because of the element of impatience with which we are all endowed, we tend erroneously to conclude that he has overworked it. Certainly the practical politician proves generally to be in too much of a hurry, and his stock in trade is to play upon mass impatience. But quite apparently, as the fruits of technology enter more and more intimately into our lives, it becomes increasingly difficult to resist the urge to over-accelerate the tempo of political and sociological change.

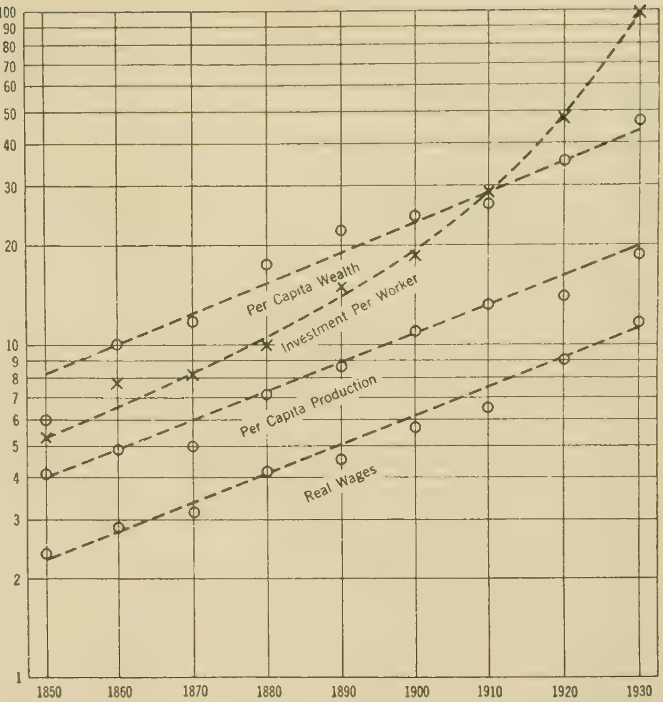
Real Wages Advance With Production

Granting, as we must, that the economist's "in the long run" makes his conclusions seem exasperatingly detached, it should be helpful to recall very briefly certain advances which the past 80 years of industrial history in the United States have seen accomplished. While searching recently for data capable of very condensed statement and yet basically significant, I chanced upon a combination that made an instant appeal to me. They do not tell a new or unsuspected story, but they do so definitely assert a relationship between progress in technology and progress in wage and living standards that I want to reproduce them.

In considering the accompanying figure, note first the curve which on an arbitrary scale (which is unimportant since the ordinates are logarithmic) indicates the growth of the per-capita wealth of the United States. In plotting this curve an attempt has been made to use a fixed unit in the measurement of wealth, thus eliminating fluctuations in price level. Over a period of 80 years, per-capita wealth with minor variations has shown a steady growth from the arbitrary value of 8 in 1850 up to more than 40 in 1930—roughly a fivefold increase. It would be beside the present point to argue the thesis that the fundamental source of this increase in per-capita wealth has been in the voluntary savings of the people.

Note next the curve indicating the growth of per-capita production over the same 80 years. We see that from the arbitrary value 4 it rises to about 20—again approximately a fivefold increase. In other words, over the period of 80 years, per-capita wealth and per-capita production have moved essentially in step.* (It should be recalled that on the logarithmic scale, equal differences between ordinates mean equal ratios between the quantities the ordinates represent.)

Now, as per-capita production has gone up, what has happened to wages? Of course, we are not interested in money wages or hourly rates of pay. We want to know



Statistics showing relationship between progress in technology and in wage and living standards

The data of this graph are for the United States. Figures for wealth and production are from Carl Snyder; those for real wages from "Income and Economic Progress" by H. G. Moulton; those for investment per worker from W. I. King

what has happened to yearly purchasing power. The answer is contained in the curve labeled "real wages." Beginning with an arbitrary value of 2.3 in 1850, real wages have mounted steadily to a value of 12 in 1930—again a fivefold increase. Not only, therefore, have real wages advanced as rapidly and *no more* rapidly than per-capita production, but both of these have advanced as rapidly and again *no more* rapidly than per-capita wealth.

While time will not permit a detailed discussion of the relationships suggested by the curves, I want to say that they leave with me the impression of being very fundamental. If over a period of 80 years—and we cannot say that these have been years unattended by intense labor agitation—we find that real wages have kept virtually perfect step with per-capita production, it suggests, does it not, that if we want to continue to increase real wages the very best way to proceed is to strive for further enlargement of per-capita production. In these curves we see renewed evidence that the basic interests of capital and labor are identical. Moreover, per-capita production and per-capita wealth are linked almost as the hen and the egg. To increase production brings with it the possibility of increasing savings and wealth; and only by increasing wealth, primarily in the form of improved capital goods, can production be augmented and real wages raised.

Problems of Instability

I wish that it were possible at this point to give a curve tracing the trend of employment over the same period of

* It may be noted that if we assume as constant the rate at which wealth makes production possible, and also as constant the fraction of each year's production which takes the form of capital goods representing an addition to wealth, the relation shown as having existed between wealth and production becomes a necessary one.

time. Unfortunately the United States Census data have but an uncertain bearing upon the much-disputed matter of technological unemployment. Nor should we expect it to be otherwise, since the subject is one of many facets. Thus we recognize in a general way that the advance of technology has reduced the amount of child labor during the past century and a half, and again that it has permitted a reduction in the number of hours in the workday. These are important manifestations of technological unemployment. Indeed, they may well be the most important! But scientific and engineering progress has also caused shifts of labor from declining industries to growing industries, and we are entitled to assume that such shifts have not occurred without a considerable but unmeasured amount of hardship on the part of many of the individuals affected by the shifts. Doubtless the judgment of society as a whole is that this hardship is far outweighed by the collective gains inherent in the beneficent forms of technological unemployment.

But what about the decade through which we have just passed? Is it safe to assume that the present slack employment is temporary and that technology has not suddenly and quite unwittingly brought the nation to a state of potential overproduction as regards many types of consumer goods? Considerable groups of people incline to the pessimistic view, and I shall not attempt to argue contrariwise, except to point out that the pessimists are forced to admit that the supposed condition of excess of productive capacity has come about quickly. This admission, by the nature of the case, weakens their contention. Social changes usually proceed slowly, and it is unlikely that public taste and obsolescence have been so quickly satiated in important respects.

To illustrate this point further, notice that the figure carries a fourth curve showing the change that has taken place in 80 years in factory investment per worker. From an arbitrary value of 5 in 1850 it rose to 100 in 1930, a 20-fold increase. In other words, factory investment has gone up four times as rapidly as wealth in general, and four times as fast as production. Nor is there reason to suppose that this trend has ceased. It seems inevitable that with the increasing complexity of industry the investment per worker must continue to rise. This fact points to several interesting conclusions, none more important I believe than this: that the growth in complexity of industry and the requirements for ever-increasing amounts of investment per person employed create a stabilizing influence. Technological unemployment, for instance, which is caused by the undermining of an old industry by a new, will become increasingly susceptible of control as larger amounts of capital are required to initiate and expand new industries. Outmoding of the old will continue, but at rates sufficiently retarded to mitigate the problems of readjustment. The importance of an adequate national savings program is also seen in a new light. As industry requires steadily increasing amounts of capital funds per worker to advance and expand, the necessity of augmenting our national wealth stands out in a new light—and the nonproductive consumption of wealth and of labor are matters for searching review.

In conclusion, let me repeat that I have introduced these curves, not so much to illustrate specific conclusions as to establish the fact that in the nature of things long periods of time must be at the bottom of most political-economic discussions and studies. Even the engineer, already accustomed to the long-term point of view, may need to school his patience; as for the lay public, such instruction is vital. Had we fixed our attention upon a 10-, a 20-, or even a 30-year period, the basic relationships existing between wealth, production, and wages would have been largely masked under the variation of other factors which because of the complicated nature of the problem could not be eliminated or compensated for with assurance. To appreciate this we have but to look at the 10-year values plotted in the figure and note how wide some of them fall of the straight lines which, taken together, they clearly determine. To neglect the long-term trend is likely, therefore, to lead to erroneous conclusions regarding the natural forces at work in society; and to misjudge these can result in as serious consequences as to be in error regarding the basic laws of physics and chemistry.

World Telephone Statistics

OF THE 37,098,084 telephones in service on January 1, 1937, approximately one-half, or 18,433,400, were in the United States, according to a survey recently compiled by the American Telephone and Telegraph Company. By continents, there were 19,952,423 in North America, 13,513,152 in Europe, 1,690,978 in Asia, 840,880 in Australia and other Pacific Islands, 765,435 in South America and 335,216 in Africa. Of the total number of telephones in use about 93 per cent could be reached by a subscriber in the Bell System. Private companies operated 22,538,753 or 61 per cent and government systems the remainder. There were 18,300,000 automatic or dial telephones. Two American cities, Washington, D. C., and San Francisco, Calif., lead the world's urban service with 37.43 and 37.00 telephones per 100 inhabitants, respectively, followed by Stockholm, Sweden, with 34.78 and Denver, Colo., with 30.96.

Countries	Number of Telephones	Per Cent of Total	Telephones per 100 Population	Number of Telephone Conversations
United States	18,433,400	49.69	14.39	26,800,000,000
Germany	3,431,074	9.25	5.08	2,562,000,000
Great Britain	2,791,597	7.53	5.93	2,000,000,000
France	1,481,788	4.00	3.51	941,000,000
Canada	1,266,228	3.41	11.48	2,449,192,000
Japan	1,197,129	3.23	1.70	4,772,000,000
Russia	950,000	2.56	0.55	
Sweden	687,566	1.85	10.97	1,000,000,000
Australia	562,868	1.52	8.31	514,000,000
Italy	560,660	1.51	1.31	
All others	5,735,774	15.45		
Total	37,098,084	100.00	1.71	

Electricity as an Industrial Fire Hazard

OF ALL FIRES in the United States and Canada during the years 1936 and 1937 (excluding those where lightning was the initial cause) 11.2 per cent were of electrical origin, and the loss was 10.9 per cent of all fire loss. These figures from the records of the National Fire Protection Association indicate that for all types of property, electricity ranked third as a cause of fire. The records of the Associated Factory Mutual Fire Insurance Companies on the same basis show that for industrial plants, electricity rates a strong first. For the years 1931 to 1938 inclusive, 19.8 per cent of the fires for which claims were made in Factory Mutual plants were caused by electricity, and the loss was 19.2 per cent of their total fire loss. That is, one out of every five fires was of electrical origin.

That the figures for industry should be greater than for the country as a whole is logical and easily explained. The average amount of electrical equipment in industrial plants is much larger than the average of such equipment in all classes of properties throughout the country, which includes dwellings, mercantile buildings, and many other kinds of structures. Every type of equipment made is found in industrial plants and the amount of this equipment and the size of individual pieces of apparatus is sometimes very large.

The following figures obtained from the Factory Mutual appraisal division give some idea of the proportional values of electrical equipments to the total insured values for several different kinds of modern manufacturing properties:

Type of Industry	Per Cent of Total Insured Value Represented by Electrical Equipment
Fully electrified newsprint mill	20.6
Up-to-date cotton mill	4.1
Hosiery mill	3.7
Lace-curtain mill	4.1
Average machine shop	2.8
Rubber product manufacturing plant	7.6
Large plant making electrical apparatus	12.0
Laundry	6.4

Of the various types of electrical equipment, wiring is responsible for 41.2 per cent of all the electrical fires; this includes all transmission, distribution, and branch circuit conductors in plant yards and buildings, all materials, devices, and fittings necessary for complete wiring systems, and lamp pendants with their drop wires, sockets, receptacles, attachment plugs, and the like. The resulting loss amounts to 66.4 per cent of all electrical-fire loss. The proportion of loss is exceptionally high, because fires of this class are more likely to spread and cause sprinklers to discharge water.

An additional 27.7 per cent of all fires of electrical origin start in motors. They cause 16.7 per cent of the electrical-fire loss. The reason the percentage of loss is less than the percentage of electrical fires is that usually these fires are confined to the machines and do not spread. Motor controllers, starters, and circuit breakers also are types of apparatus where trouble causing fires frequently originates. Such equipment causes about 16.6 per cent of Factory Mutual electrical fires. The loss they occasion is about 7.8 per cent of the total electrical-fire loss.

Lightning is the cause of an additional 5 per cent of claims for damaged electrical equipment made on Factory Mutual companies. In perhaps more than 90 per cent of the instances where industrial equipment has broken down during lightning storms, the lightning itself has not directly struck the equipment or conductors; the breakdowns are caused by high voltage resulting from the secondary effects accompanying lightning.

The average yearly number of fires of electrical origin for the years 1926 to 1930 inclusive, that is, the years immediately preceding the "depression," was 16.5 per cent of the number of all fires, while the loss caused by these fires was 17.6 per cent of the total fire loss. Comparing these percentages with the corresponding percentages for the years 1931 to 1938 inclusive, namely, 19.8 and 19.2 per cent, respectively, shows that the increase in number of electrical fires since 1931, or since the effects of the depression were felt, is 12.4 per cent. This increase has occurred during times when the electrical equipments generally were operating at reduced capacity and possibly some of them not at all. As electrical equipments have not been used as near their capacities since the start of the depression as before, when production generally was proceeding at high rates, it would naturally be expected that there would have been a reduction in the proportion of electrical fires and amount of loss experienced rather than an increase.

The answer to the question, "Why the increase?" is that since the start of the depression, the general level of quality of maintenance of electrical equipment has been very much lower than before. It is thought that at least one-third, and probably as many as one-half, of all fires originating in electrical equipment can be attributed to lack of care. Almost all manufacturing plants curtailed their maintenance efforts during the depression. Some did this to keep step with the lessened wear and tear, but many went further and cut down maintenance much more than was wise, undoubtedly with the thought that when business picked up again and the load on their equipments increased, they would give it more care and put it into good shape again before depreciation became excessive. However, many did not do it, with the result that breakdowns have occurred at an increased rate and the electrical loss has mounted.

Unless what appears to be a general let down in maintenance efforts is corrected, loss of property and production due to fires of electrical origin is likely to be serious in the future. The present low level of maintenance efforts should be raised and electrical equipments should be given the attention their importance warrants.

Abstracted from a paper by G. S. Lawler (A'11, M'13) chief electrical engineer, Associated Factory Mutual Fire Insurance Companies, Boston, Mass., presented at the Fire Service Extension School, West Virginia University, Morgantown, July 27, 1939.

Optimum Voltage for Airplanes

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Standardization of aircraft equipment is desirable when such standardization does not interfere with efficient operation. Equations developed for the standardization of electrical equipment indicate that the voltage for a large number of airplanes with d-c systems using storage batteries to carry peak loads can be standardized advantageously at 24 volts.

AIRPLANES are flying every day with even the major electrical units, such as generators, batteries, and motors, far heavier than necessary; but efforts to obtain ever higher airplane performance, together with the period of design refinements that follows in the wake of an initial "mushroom" development, are necessitating a review of past growth and the establishment of sound bases for future designs.

One extremely practical factor that must be kept in mind is standardization. This is particularly true of military airplanes, which cover the extreme range of types and sizes, and which also are called upon to operate from far-flung and isolated supply bases, where the maintenance of a multiplicity of replacement parts is not possible. The engineer, then, is forced to make a compromise between optimum design conditions for a particular application, and adherence to standard and available designs. However, it does not take much of a difference in weight to turn him toward the lighter, though nonstandard design.

Of the multitude of research problems involved in adapting complete electrical systems to a basis of minimum weight for a required job, the fundamental problem is that of power-supply-system characteristics. At present, d-c generators in parallel with lead-acid storage batteries provide an acceptable source of electric power in all but the largest airplanes.

The wiring installation of a military or transport airplane consists of insulated copper conductors of various sizes (number 20 to 00, American wire gauge) enclosed in thin-wall rigid or flexible aluminum conduit, with junction boxes and other fittings forming a complete metal-enclosed system. The remaining equipment, including generators, batteries, motors, lights, solenoids, radio transmitters and receivers, heating devices, and other units, usually is constructed according to fundamentally conventional designs and is used in all classes of airplanes.

Earlier types of airplanes carried little electrical equipment, and the use of 12 volts as standard was satisfactory. With increase in size and better performance in all classes of airplanes there was a considerable increase in weight of the electrical equipment and the determination of the optimum voltage, which is the voltage for which the weight of electrical equipment is a minimum, became more important. Calculations were made to determine the optimum voltage. These calculations were long and tedious since they required a calculation of the weight of the system for several voltages. The curve of weight versus voltage based on these calculations indicated that there was a voltage for which the weight was a minimum and that there was a considerable range of voltage over which the weight was very little more than the minimum. This range is referred to as the minimum region. In making these calculations certain assumptions had to be made as to the manner in which the weight of the component parts of the system changed with voltage. It was found that by making slight modifications in these assumptions they could be expressed in mathematical form. The analysis that follows shows how the equations used to express these assumptions lead to equations giving the optimum voltage and the minimum region in terms of certain constants associated with the weight of the electrical equipment.

Application is made of these equations to existing airplane electrical systems to show how their use facilitates the selection of the optimum voltage.

Development of Equations for Optimum Voltage

The following treatment of the effect of voltage on the weight of the system is developed after assuming that the weight of the component parts changes with voltage in the following manner:

1. The weights of generators and load equipment (motors, lights, etc.) are approximately independent of voltage.

2. The weight of a storage battery for a given watt-hour capacity is made up of a constant plus a quantity K_2E which is a direct function of the number of cells and hence indirectly a function of voltage, or

$$W_b = K_0 + K_2E \quad (1)$$

3. The weight of cable and conduit is assumed to be related to the voltage as indicated under A, B, or C:

A(1). The weight of conductor varies inversely as the square of the voltage except that portion under $3A$(3).

(2). The weight of conduit and insulation varies inversely as the voltage.

(3). A certain weight of cable and conduit is independent of the voltage.

B(1). The weight of conductor varies inversely as the square of the voltage.

(2). The weight of conduit and insulation varies inversely as the voltage.

C. The weight of cable and conduit varies inversely as the square of the voltage.

Within the voltage range considered safe for airplane operation the weight of generator and load equipment given under 1 is sufficiently correct for all practical purposes. For lights, switches, fuses, etc., the change in

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weight with voltage is small and in this voltage range the changes may be neglected.

In private communications to the authors C. B. Mirick of the Naval Research Laboratory and H. D. Wilson of the Auto-Lite Company have shown that to a close approximation the change in weight of storage batteries of a given type with voltage for a given watt-hour capacity may be represented by equation 1. Their calculations were made for voltages from 6 to 48 volts. In figure 1 are shown changes in weight of storage batteries with voltage for one-half-kilowatt and one-kilowatt output, for periods of 5 and 20 minutes, respectively. The data are based on batteries now in the service.

The range of K_2 for these batteries is from 0.6 to 0.85. In earlier types of aircraft batteries K_2 was found to lie between 1.35 and 1 pound per volt, for the outputs shown in figure 1. The latter value was used in several earlier calculations and some of the results are given here using $K_2 = 1$ instead of 0.85. The value of K_2 changes with the watt-hour capacity of the battery, but not with the voltage, and so may be regarded as a constant in subsequent differentiation with respect to voltage.

Assumption $3A(1)$ is strictly true if for each voltage the size of the conductor is selected so as to keep the percentage voltage drop constant.

Assumption $3A(2)$ states that the weight of conduit and insulation changes inversely with the voltage. A more exact equation would indicate the cross-sectional area of the insulation, and the conduit would change with the average radius multiplied by the thickness. Since the thickness of the insulation of the cable does not increase uniformly with the size, but with groups of sizes, an equation that would exactly express the relation between weight of insulation and size of cable is beyond the scope of this investigation. As will appear later little difference is obtained in optimum voltage whether this assumption or $3C$ is used.

Assumption $3A(3)$ is made because in many types of airplanes there are low-candlepower lights, indicating devices, etc., which require such small currents that mechanical strength limits the size of the conductor rather than electrical resistance.

Assumptions $3B$ are not as close an approximation to the actual relation between weights and voltage as $3A$, and $3C$ is not as close as $3B$.

The weights of the electrical equipment of any one airplane, according to assumptions 1, 2, and $3A$, may be stated as follows:

Weight of generator, motors, etc ,

$$W_g = K_1 \tag{2}$$

Weight of batteries is given by equation 1.

Weight of conductor which is larger than the smallest allowable size and therefore changes inversely as the voltage squared

$$W_w = K_3/E^2 \tag{3}$$

Weight of conduit and insulation which changes inversely with voltage

$$W_c = K_4/E \tag{4}$$

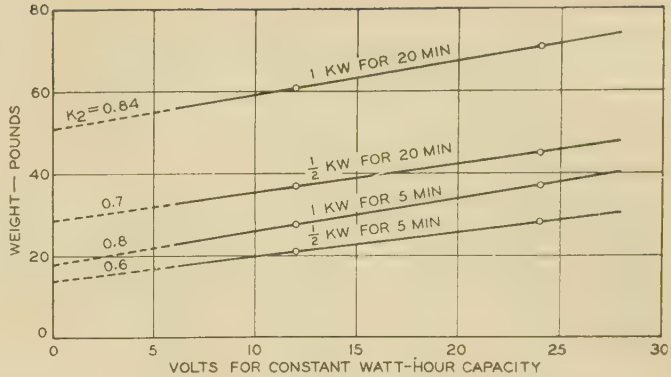


Figure 1. Curves for batteries showing change in weight with voltage for the outputs indicated, as computed from equation 1

Weight of cable and conduit which is of the smallest allowable size and therefore is independent of voltage

$$W_{wc} = K_5 \tag{5}$$

Adding, the total weight, W, may be written

$$W = K_1 + K_5 + K_0 + K_2E + \frac{K_3}{E^2} + \frac{K_4}{E} \tag{6}$$

Strictly speaking, K_5 is not a constant, but is a function of voltage, since if the voltage were very low, all the conductors might have to be larger than the smallest size having sufficient mechanical strength, while if the voltage were sufficiently high, a large proportion of the conductors might be of the smallest practicable size. However, as will be shown later large changes in the values of K_3 and K_4 within the range of reasonable designs, have little effect on the final result. If K_5 for any one airplane does change with voltage, most of the effect of the change is compensated by corresponding changes in K_3 and K_4.

Differentiating equation 6, putting the derivative equal to zero, and solving the resulting equation gives the voltage designated E_0. This is called the optimum voltage because it is the voltage for which the system has a minimum weight.

$$\frac{dW}{dE} = K_2 - \frac{2K_3}{E^3} - \frac{K_4}{E^2} = 0 \tag{7}$$

or

$$E_0(K_2E_0^2 - K_4) = 2K_3 \tag{8}$$

which gives the optimum voltage for assumption $3A$.

If

$$W_{wc} = K_5 = 0 \tag{9}$$

equation 6 satisfies assumption $3B$, providing W_w is the total weight of conductor and W_c the total weight of insulation and conduit. The optimum voltage is again given by equation 8 which is written

$$E_0(K_2E_0^2 - K_4') = 2K_3' \tag{10}$$

the constants K_3 and K_4 being written as K_3' and K_4' to distinguish the assumption under $3B$.

If $W_{wc} = K_5 = 0$ and $K_4 = 0$, this means that the total weight of cable and conduit changes inversely with the

Table I. Optimum Voltages for Several Airplanes, and Increase in Weight (Pounds) if Voltage Is Standardized at 24 Volts and at 12 Volts; $K_2 = 1$

1	2	3	4	5	6	7	8
Weight of Cable and Conduit of 12-Volt System	Weight of Conductor	Weight of Conduit and Insulation	Optimum Volts, Equation 11	Optimum Volts, Equation 10	Optimum Volts, Equation 8	Increase in Weight if 24 Volts Is Used Instead of Optimum Voltage Given by Equation 11	Increase in Weight if 12 Volts Is Used Instead of Optimum Voltage Given by Equation 11
10	7	3	14	13	12.5	5	1
20	14	6	18	18	16	2	5
50	35	15	24	24	22.5	0	25
70	49	21	27	28	25	0	40
100	70	30	30	32	29	3	65
150	105	45	35	37	33	10	110
200	140	60	38	41	37	15	155
300	210	90	44	48	43	30	245
400	280	120	49	54	48	50	340
500	350	150	52.5	59	53	70	435

voltage squared. This is assumption $3C$, and equation 8 may be written

$$E_0 = \left(\frac{2K_3''}{K_2}\right)^{1/3} \tag{11}$$

Since W_w in equation 3 designates the total weight in accordance with assumption $3C$, the constant K_3 is designated by K_3''.

The constant K_1 which designates the weight of the generator, motors, etc., is of no importance in determining either the shape of the curve or the optimum voltage, and in the following computations is omitted. The weight of the system without the generator is designated W'. Equation 6 may then be written for the weight of battery, cable, and conduit according to assumptions $3A$, $3B$, and $3C$.

Assumption A:

$$W' = K_0 + K_2E + \frac{K_3}{E^2} + \frac{K_4}{E} + K_5 \tag{12}$$

Assumption B:

$$W' = K_0 + K_2E + \frac{K_3'}{E^2} + \frac{K_4'}{E} \tag{13}$$

Assumption C:

$$W' = K_0 + K_2E + \frac{K_3''}{E^2} \tag{14}$$

Computations

In table I are shown the results of computations for several airplanes which, if equipped with 12-volt systems, would require the combined weights of cable and conduit shown in the first column. Columns 2 and 3 show the weights of conductor and conduit and insulation, respectively, on the assumption that 70 per cent of the combined weight is that of the conductor. The optimum voltage for each airplane, as calculated from equation 11, appears in column 4. In these computations the battery constant K_2 is taken as 1 for all weights of cable and conduit. If it is assumed that the airplane with the greatest weight of cable and conduit requires the largest battery, then K_2, if it changes at all, probably will increase with increase in weight of cable and conduit. An inspection of the equations shows that with an increase in K_2 the optimum voltage will be decreased, and if K_2 increases with the size of the plane the optimum voltage for the heavier units will agree more nearly with that for the lighter units than is indicated by the values in table I. Using the single value $K_2 = 1$ for all weights of cable and conduit gives the maximum difference between the optimum voltages for the large and small units.

The other constant K_3'' appearing in equation 11 was calculated for each airplane from equation 3, using for W_w the combined weight of cable and conduit for a 12-volt system, since for the conditions under which $K_3 = K_3''$, the value of W_w is the combined weight of cable and conduit shown in the first column.

In column 5 are given the optimum voltages calculated from equation 10. The constants K_3' and K_4' were calculated for each airplane from equations 3 and 4, respectively, using for W_w the values from column 2, and for W_c those from column 3, since for the conditions under which $K_3 = K_3'$ and $K_4 = K_4'$, the value of $K_5 = 0$.

The optimum voltages in column 6 were calculated from equation 8, with the assumption that the part of the weight that is independent of voltage consists of 20 per cent of the weight of conductor and 30 per cent of the weight of insulation and conduit in the 12-volt system.

Table I indicates that although the assumptions leading to equations 8, 10, and 11 are different, the calculated optimum voltages are nearly the same.

Column 7 shows the increase in weight by adopting 24 volts instead of the optimum voltage computed from equation 11. Column 8 shows the increase in weight by adopting 12 volts instead of the optimum voltage. A decided saving in weight is indicated by adopting 24 volts instead of 12 volts.

Optimum Voltage for Five Airplanes

In columns 2, 3, and 4 of table II are given the total weights of cable and conduit, the weight of cable and the weight of conduit respectively, for five different types of airplanes. Since it is difficult to estimate the weight of insulation on the cable, the constant K_3' is obtained by using the weight of the cable as the weight of the conductor, and K_4' is calculated from the weight of the con-

Table II. Weight (Pounds) of Electrical System of Five Airplanes, and Increase in Weight if Voltage Is Standardized at 12 Volts and at 24 Volts

1	2	3	4	5	6	7	8	9
	Weight of Cable and Conduit for a 12-Volt System				Difference in Weight Between			
					E_0 and 12 Volts, Equation		E_0 and 24 Volts, Equation	
Airplane*	Total Weight	Weight of Cable	Weight of Conduit	Per Cent of Cable Weight to Total Weight	14	13	14	13
A	22.9	11.6	11.3	50.7	8	5	1	1
B	33.21	16.81	16.4	50.6	15	11	0	0
C	54.49	30.46	24.03	55.9	31	25	0	0
D	111.85	77.75	34.1	69.5	79	71.5	5.5	6.5
E	204.5	119	85.5	58.2	162	145	19	23

* Airplane A is a single-seat type, B a two-seat type, and C a three-seat type; D is a small twin-engine type, and E a large twin-engine type.

duit; K_3'' is based on the total weight given in column 2, using equation 3. Substituting these values in equations 10 and 11, with K_2 taken as 0.85, the optimum voltages are obtained. Columns 6 and 7 show the increase in weight if 12 volts is used instead of the optimum voltage. In columns 8 and 9 are given the increases in weight that would result from using 24 volts instead of the optimum voltage. The agreement between these two columns indicates that it is not important whether the optimum voltages are computed from equation 13 or 14 for the range of weights covered by these airplanes. The ten curves in figure 2 show the change in combined weight of battery, cable, and conduit with voltage using equations 13 and 14.

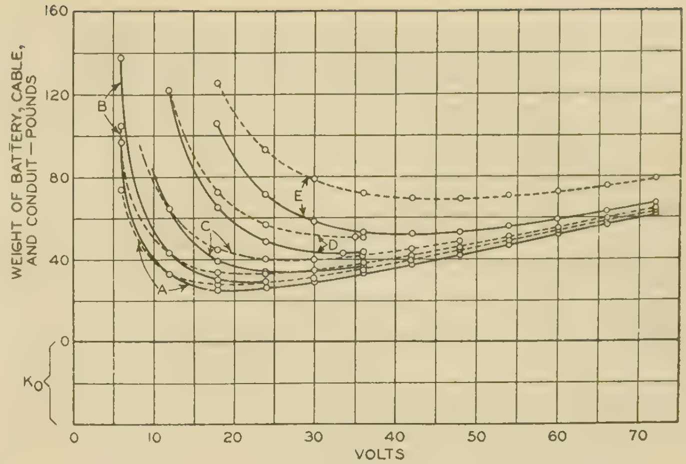


Figure 2. Curves showing change in weight of equipment with voltage for the five airplanes listed in table II

Curves with solid lines computed from equation 14; with dashed lines, from equation 13

Discussion of Results

In determining the optimum voltage for a large number of airplanes, some of which are in use and some of which have not yet been designed, it was necessary to make broad but reasonable assumptions as to how the weight of electrical equipment will change with voltage. The calculations for this change in weight are based upon the assumptions 1, 2, and 3 given hereinbefore, that all generators, batteries, cables, and conduits have a voltage-weight relation that holds for all sizes of airplanes. The calculations may be said to apply to many classes of airplanes whose constants K_3', K_3'', and K_4' cover a range for which the ratio of the largest to the smallest value is 50 to 1.

The shape of the curves depends upon K_2, K_3, and K_4. The constant K_2 changes so slowly with a change in the size of the battery that it may be taken as a constant over a considerable range of battery sizes. Constants K_3 and K_4 depend upon the weight of the cable and conduit, and by using these as parameters a family of curves is obtained all of which have the same general shape. The optimum voltages are determined by the shape of the curves rather than their positions, and since the change in weight with voltage is slow in the neighborhood of the optimum voltage, the curves may be said to have a minimum region. It is because of this slow rate of change in weight with voltage that such good agreement is obtained for the wide range of values using the three diverse assumptions 3*A*, 3*B*, and 3*C*.

The assumption that the weight of the cable is 70 per cent of the total weight of cable and conduit was true for only one airplane as shown in column 5 of table II. However, as shown in figure 2, the curves plotted from equation 14 for the smaller weight of cable and conduit are almost identical with the curves plotted from equation 13, notwithstanding the difference in assumptions.

Referring to equation 11 it may be seen that the optimum voltage depends upon the weight of cable and conduit and the constant K_2. This constant for the two larger batteries for which curves are shown in figure 1 is for all practical purposes the same, since it changes less by doubling the capacity than the uncertainty of the other factors entering into this equation. This means that to a reasonable approximation the optimum voltage is independent of the watt-hour capacity of the battery, which seems somewhat paradoxical. In practice, this means that once the optimum voltage is determined, the discharge rate and output of the battery may be changed without affecting the optimum voltage, notwithstanding that the total weight of the battery is changed by changing the output.

The increase in optimum voltage with a decrease in K_2 suggests that with more efficient batteries a higher operating voltage is desirable. A recalculation of the values using $K_2 = 0.85$ instead of 1, would indicate higher optimum voltages in columns 4, 5, and 6 of table I.

The values given in table II are for $K_2 = 0.85$ and indicate 24 volts is the optimum voltage for the single-engine type. For the twin-engine type the voltage should be higher, but if a single voltage is to be selected for all classes of planes 24 volts seems to place the additional weight in the larger planes, which ordinarily should be able to take care of it.

Conclusions

Stated briefly the equations indicate the following:

1. While the computed weight of the system will change, the shape of the curves will be approximately the same whether assumptions 1 and 2 are combined with 3*A*, 3*B*, or 3*C*, at least for the range of weights covered by table I. The curves may be used to select the optimum voltage that will give approximately the minimum total weight in each case. The capacity of the battery selected will affect the absolute weight of this system, but the optimum voltage should not be greatly changed.

2. For airplanes of the single-engine type, standardization on 24 volts seems to meet the requirements for a large number of airplanes. For airplanes having 10 pounds of cable and conduit or less, there may be an increase in weight of 5 pounds or more if one of the existing types of 24-volt batteries is used. If batteries having a smaller increase in weight with increasing number of cells are developed, the penalty for this choice of higher voltage will be less.

3. For large airplanes where auxiliary power plants are used, it may be desirable to supplement the standard 24-volt generator-battery system with a higher-voltage a-c or d-c system without battery.

Transactions Supplement for 1939 to Be Issued Soon; Its Contents Are Outlined Here

IN ADDITION to the 95 technical papers which together with their related discussions will have been preprinted in the monthly TRANSACTIONS sections of ELECTRICAL ENGINEERING by the close of the current calendar year, 28 others will be included in the 1939 annual volume of AIEE TRANSACTIONS. For the convenience of members and subscribers who desire to secure a complete file of these 28 technical papers and their related discussions, a special "TRANSACTIONS Supplement" will be published in December. This supplement together with the 12 issues of ELECTRICAL ENGINEERING for 1939 will provide in complete form *all* the technical papers and discussions published by the Institute during the year.

Advance orders are required because the number of copies to be printed will be determined by the demand. Therefore members should be on the alert for the order form which they will receive soon through the mails. This year's supplement contains 240 pages and will be paper bound similar to ELECTRICAL ENGINEERING; the price is 50¢ per copy.

To acquaint members with the content of this year's supplement, brief abstracts of the 28 papers to be included are given on this and the following pages.

Basic Sciences

CURRENT Distribution in a Rectangular Conductor, *John L. Daley* (*A'36*). The extensive use of rectangular conductors for large alternating currents has made the determination of their electrical characteristics a problem of practical importance. Although these conductors are usually used in groups and in special configurations, no solution other than that of direct measurement has been given even for the basic problem of the distribution of current in a single isolated conductor. The mechanical complications of the direct-measurement method are great, and the results obtained are necessarily an approximation. The current density inside a rectangular section may be determined analytically if the surface current density, comparatively easy to obtain, is known. The method is partly experimental and partly analytical.

TWO-PHASE Co-ordinates of a Three-Phase Circuit, *E. W. Kimbark* (*M'35*). In recent years there has been an increasing interest in the use of substituted variables in the analysis of unbalanced three-phase circuits and machines. The best known and most widely used method is that of symmetrical components, in which the actual currents and voltages of the three phases are replaced by the zero-sequence, positive-sequence, and negative-sequence currents and voltages, and the three-phase circuit by three single-phase circuits; another method is the use of direct-axis and quadrature-axis quantities which has facilitated the analysis of salient-pole synchronous machines. A new set of substituted variables, which may be found simpler to use than symmetrical components in the analysis of certain types of unbalanced three-phase circuits, is related both to symmetrical components and to the direct- and quadrature-axis quantities, but differs from either. The name "two-phase co-ordinates" is proposed because the three-phase circuit to be analyzed is replaced by an equivalent two-phase circuit and a single-phase circuit similar to the zero-sequence network. Probably the chief application of the new method is in the field of power distribution, with its single-phase loads, unsymmetrical transformer connections, untransposed lines, and mixtures of three-phase and two-phase circuits.

VALUES of the Bessel Functions ber x and bei x and Their Derivatives, *H. B. Dwight* (*F'26*). The functions ber x and bei x and their derivatives are used frequently in electrical-engineering problems connected with heavy conductors and with wires at radio frequencies. For instance, current distribution and resistance loss in a round conductor, or in a coreless induction furnace, are often computed by means of these functions. Tables now have been computed for values of x from zero to 20, at intervals of 0.1 to five significant figures.

EFFECT of Corona Discharge on Liquid Dielectrics, *Joseph Sticher* (*A'30*) *and D. E. F. Thomas* (*A'30*). The proper functioning of much electrical equipment depends on electrical insulating mediums, such as oils, under conditions known to include corona discharge. Pure liquid paraffin, various cable oils, and ten hydrocarbons of known-type molecular structure have been studied in a test cell, and several of their characteristics were found to be changed by corona discharge. The power factor of all samples increased with bombardment, while in most instances the d-c conductivity of bombarded samples was considerably lower than the a-c conductivity calculated from power-factor values. Application of d-c potential to bombarded decalin for extended periods showed a temporary decrease in power factor and conductivity. The material responsible for changes in power factor and conductivity was found to constitute an extremely small portion of the bombarded oil. Currents resulting from application of identical a-c bombardment voltages to the test cell and gas evolution under bombardment were widely different for the various oils, while in practically all cases an increase in viscosity resulted from the bombardment of the oils.

THE Generalized Solution for the Critical Conditions of the Ferroresonant Parallel Circuit, *William T. Thomson* (*A'37*). A generalized treatment for the critical conditions of the ferroresonant parallel circuit yields a number of interesting conclusions to supplement those found for the series circuit in a recent paper. Unlike the series circuit with its voltage-sensitive characteristics, the parallel circuit is known to be current sensitive in the critical region. The critical current is greatly dependent on the value of capacitive reactance used, and as in the series circuit, this current increases with a decrease of capacitive reactance. Although applications of the parallel circuit are rather limited compared to those of the series circuit, the constant-current characteristics of the parallel circuit may be in some places where it is necessary to maintain a constant voltage in spite of fluctuation in line voltage. This constant voltage may be obtained by placing a constant impedance in series with the parallel circuit tuned to the critical stable condition. A negative-slope characteristic of the parallel circuit may be utilized to advantage when applied to a resistance thermometer.

SUBHARMONICS in Circuits Containing Iron-Cored Inductors—II, *Irven Travis* (*A'32*). With the assumption that the reader is familiar with an earlier paper ("Subharmonics in Circuits Containing Iron-Cored Reactors," Irven Travis and C. N. Weygandt, AIEE TRANSACTIONS, volume 57, 1938) the production of subharmonic oscillations in a series circuit consisting of a capacitor and an iron-cored inductor is studied by the method of matching boundary conditions. The calculations are carried out by means of a new mechanical calculating device, and are verified by differential-analyzer solutions. A sufficient, but not necessary, criterion for stability is deduced. Some consideration is given to the effect of resistance in the circuit, its effect on stability being of greatest importance in the region of saturation. Good accuracy can be attained in the calculations by this method provided the circuit is such as to admit of certain idealizing assumptions and the oscillations are stable.

Communication

THE Role of the Ionosphere in Radio Wave Propagation, *J. H. Dellinger*. Radio waves are reflected and caused to travel great distances by the ionosphere, or ionized region in the upper atmosphere. The ionized condition does not increase uniformly as the air pressure decreases with altitude, and because of varying distribution of chemical composition of air with height, there are certain strata or layers in the air in which a maximum of ionization exists. Sky-wave transmission is determined by, and calculable from, the heights and ionization densities and other properties of the ionosphere layers. The maximum usable frequencies at any distance, for instance, are directly determinable from the virtual

heights and critical frequencies measured in vertical-incidence experiments. Optimum frequencies similarly may be estimated, though not as certainly as the maximum usable frequencies. The received intensities of the waves may be estimated to a certain extent from ionosphere data, but much more extensive data are needed for this purpose.

HARMONICS in the A-C Circuits of Grid-Controlled Rectifiers and Inverters, *R. D. Evans (M'26) and H. N. Muller, Jr. (A'37).* A well-known property of all rectifier- and inverter-type apparatus is the production of harmonic distortions in both the current and voltage wave shapes on both the supply and output circuits. A theoretical method has been developed for predetermining the magnitude of the harmonics in terms of the d-c load current, the commutating reactance, the rectifier transformer secondary voltage, and the amount of grid control. Harmonic voltages in the supply circuit may then be calculated from the harmonic currents and the supply-circuit reactances at the various harmonic frequencies. General curves facilitate the calculation of the harmonic currents for the range of conditions usually encountered; other curves aid in the determination of the product of the supply-circuit current and its own telephone influence factor. An empirical modification of the theoretical method may be applied to a-c circuits with nonlinear frequency-reactance characteristics, such as that of a rectifier provided with a-c filtering equipment. The inverter is treated in a manner similar to that used for the grid-controlled rectifier.

THE Submarine-Cable Plow, *C. S. Lawton.* Submarine cables may be damaged by fishing gear dragged along the ocean bottom, and in areas subject to such damage some cables have been buried in trenches to a depth of from one-half to two feet. The operation was performed by a nine-ton plow that dug a trench and placed the cable in it. The plow was designed to vary the depth of trench according to the resistance of the ground, in order to prevent excessive tensions in the towline—a chain with an ultimate strength of 63 tons. Means were provided for indicating on the towing ship the cable tension at the plow, depth of burial, condition of cable ahead of the plow (whether sinking to the bottom or being pulled down), and angle of the plow on the bottom. The plow was lowered and towed from the bow of the ship. Suitable gear had to be provided for handling the chain, and a procedure for trenching agreed upon. Service interruption was minimized by choosing a route parallel to the existing cable, laying a new section of cable in a trench, and splicing the new cable into the old.

THE Submarine-Cable Depthometer, *D. H. Nelson.* The problem of plowing submarine cables into the ocean bottom (described in "The Submarine-Cable Plow," by C. S. Lawton) requires a means of checking the depth of burial of the cable after the plowing operation has been completed. The actual depth in inches below the surface of the ground is given by a magnetic detecting and measuring device that utilizes the protective sheath of iron wires on the cable. The magnetic field arising from the magnetization of the cable sheath, together with the distortion created in the earth's magnetic field by the cable sheath, generates an electromotive force in detecting coils when these coils are moved in a substantially horizontal plane through such a field. By the use of two sets of coils mounted in a sled, the influence of speed and other factors is canceled. Amplifying and recording apparatus on the towing ship is connected to the sled by a pair of wires in the towing line; depth of the cable is determined from the record. Further use has been found for the depthometer in locating cables and in determining the relative positions of two or more cables in a particular locality, after which grappling operations for the desired cable may be conducted with comparative safety.

REMOTE-Control Toll Board, *Gilbert Sorber and Arthur Bessey Smith (F'22).* Essential operating facilities placed at the disposal of toll operators for the switching and completion of long-distance calls have, in a general sense, remained substantially unchanged since the early days of toll switching. As toll systems become more complex with the extension of the system and development of new services, there is a tendency toward the adoption of new switching methods even though these methods require the toll operator to give a greater amount of undivided attention to each call during the build-up period. Development of the remote-control toll board has made it possible to retain the advantages of these new methods of toll operation, and at the same time achieve a saving in time and labor. The remote-control toll board provides for connections from local subscribers to toll, toll to local subscribers, and toll to toll by means of electromechanical switches under the control of toll operators. The application of the board is not confined to operation with Strowger central offices, since by means of trunk groups and repeaters, the automatic switches will operate with varied types of central-office systems, whether manual, automatic, or a combination of both. Line equipment can be of the ring-down type, common-battery manual, or automatic with varied dialing methods.

Electric Welding

PREDETERMINATION of Temperatures in Resistance Welds, *Walter C. Johnson (A'35).* One of the most important variables in the resistance-welding process is the temperature obtained in the region of the weld. If this temperature is too low, the parts will not unite, and if it is too high, a burned weld will result. The physical complexity of this problem has made a satisfactory mathematical solution exceedingly difficult. By extension of a simple graphical method for solving transient heat-conduction problems, many mathematically complex conditions may be handled with ease and routine calculations become simple. The analysis applies particularly to the resistance welding of comparatively thin sheets held between electrodes of equal contact areas, and covers a large percentage of resistance welds. It evaluates the temperatures, temperature gradients, and rates of heating and cooling of a cylindrical portion of the work enclosed between the electrodes as functions of both time and position along the axis of this cylinder. By determination of these quantities and a knowledge of the welding characteristics of the material, current and time for a good weld may be predetermined.

POWER Supply for Single-Phase Resistance Welders, *R. H. Wright (M'27).* The increasing use of a-c contact welders in metal-fabricating plants imposes single-phase low-power-factor fluctuating loads on the power system. To eliminate voltage disturbances, motor generators have been installed to serve as phase converters supplying single-phase power. Common applications for single-phase welding generators are associated with butt, flash, spot, and seam welders, and tube welding machines.

Each type of welding may be served best by a certain combination of motor, flywheel, and voltage regulator. Generators for butt and flash welders may be driven satisfactorily by synchronous motors, using generator field forcing for flash welding. Induction motors may be most satisfactory for spot and seam welding, perhaps with some additional flywheel effect; synchronous motors and voltage regulators may be most satisfactory for tube welding. Experience gained from past installations provides a basis for the correct application of conversion equipment for future requirements.

Electrical Machinery

EQUIVALENT Circuit Impedance of Regulating Transformers, *J. E. Clem (F'38).* As systems grow in complexity and service standards grow higher, the need for more accurate determination of system characteristics increases. From time to time the question of how to handle the impedance introduced into the circuit by a regulating transformer has arisen. Regulating transformers are in effect autotransformers, but differ from them in that the series winding is on a separate core and receives its excitation from a section of the shunt winding. This difference introduces considerable complexity into the determination of the impedance introduced into the circuit. However, the equivalent circuit impedance of regulating transformers may readily be determined by general equations.

AN AUTOMATIC Voltage Regulator Without Moving Parts Employing Ferroresonance, *Palmer H. Craig (F'38).* A new automatic line-voltage regulator operates without tubes or moving parts of any kind, and can be used for loads up to 625 kva. The operation depends upon the use of ferroresonant networks, in which iron-core devices are operated on the knee of their saturation curve in such a manner that for a slight change of applied voltage across these reactors there will be a slight change of flux in their cores. Due to the portion of the characteristic curve on which they are

worked, this change of flux will change the apparent inductance of the coil, throwing it either into or out of resonance with the associated capacitor at the frequency of the impressed voltage. A copper-oxide rectifier in the network supplies current to the d-c saturating leg of a saturable-core reactor, whose a-c coils are placed in series with the primary of a booster transformer. The secondary of the booster transformer is in series with the line. The device is claimed to require no maintenance attention nor expense, and to be highly efficient, very accurate, and much faster in its response than previous line regulators.

RECENT Developments in Generator Voltage Regulation, *C. R. Hanna (M'39), K. A. Oplinger (M'39), and C. E. Valentine (A'27).* A new rheostatic type of voltage-regulator element consists of a control member, requiring very small force and movement, arranged to vary a resistor having a large number of steps. Several silver buttons are so mounted that they may be actuated in sequence by a driving member. Each button is carried on the free end of a flat leaf spring which normally rests against a block of insulating material. The leaves are clamped together with insulation between them, and only a small movement is necessary to close the gaps between all the buttons in sequence. Each spring is connected to a tap on the regulating resistance. The same principle may be extended for relays for increasing the power-handling capacity of regulators. A mathematical treatment gives the requirements for stability and adequate damping for several typical voltage-regulating systems. It is shown that with certain systems, theoretically perfect regulation and also high damping are possible.

RESONANT-Type Constant-Current Regulators, *Roland R. Miner (M'37).* A resonant network composed of linear impedances can be contrived to maintain a constant current in one element when energy is supplied at constant voltage. There are various forms that such a regulator may take, but the underlying principles are the same for all. The resonant regulator will perform quite differently under different circumstances, and a convenient, simple method of predicting the performance of a given regulator under various conditions is helpful to those applying the device. Resonant regulators are affected by variations in the supply voltage, and usually operate at the same power factor as the load. The input current is proportional to the load; hence both open-circuit and overload protection are provided by an overcurrent device in the supply circuit. The load circuit is usually not reactive, and in case of a break there is practically no arcing, although film cutouts and similar devices operate perfectly. The efficiency is similar to that of an ordinary transformer, except that for small regulators the maximum efficiency will be near one-third load instead of three-fourths load as it is in most transformers, making the resonant regulator especially adaptable to small regulators that do not fit exactly the load to be carried. The high efficiency at light load makes it desirable for circuits that operate part of the time at half load or less.

Instruments and Measurements

ALUMINUM-Nickel-Cobalt Brake Magnets for Watt-Hour Meters, *Stanley Green (M'34).* A new permanent-magnet material with such a high coercive force that design is affected radically has been applied to watt-hour meters, where it provides economies in space and weight. The new damping unit is different from the old in size, cross section, and shape, and consists of a single horseshoe-shaped magnet on one side of the disk with a soft-iron armature opposite. Adjustment of the magnitude of damping is made by forming the armature in three pieces and moving one of them with reference to the other two in order to vary the reluctance of the flux path through the armature. Permanency in the new design has been demonstrated by tests, and the unit can be made much more resistant to transient magnetic disturbances than the common form of chromium-steel damping magnet unit. The new magnet is formed by casting, and heat treated. Its material falls within the classification of corrosion-resistant alloys, and no protective coating is necessary.

AN AUTOMATIC A-C Potentiometer and Its Application to the Nondestructive Testing of Insulating Equipment, *George Keinath (M'37).* The importance of the measurement of dielectric loss for determining the quality of high-voltage equipment has been well known for a long time by the high-voltage-cable industry, and its measurement has been included in the international regulations for acceptance tests of cables. It was obvious that the same method could be used also for testing other high-voltage devices, such as transformers, bushings, insulators, and capacitors, but manual adjustment of the bridge takes too long a time for the usual high-voltage test, which requires about two minutes, to obtain the characteristic diagram of power factor versus voltage and time. An a-c potentiometer equipped with an entirely new element, the zero motor, which serves both as zero indicator and motor for adjusting the sliding contact, can be arranged to draw a continuous record of the desired relation. Two motors, contacts, and charts are used to accommodate both active and reactive components. Large deflections over the whole ten-inch width of the paper are accomplished in not more than two seconds. The continuous diagram enables the observer to see what is going on, and to stop the test before complete breakdown.

DEMAND-Meter Time Periods, *P. M. Lincoln (F'12) and R. R. Sprole (A'36).* The demand meter has been used for many years to measure the maximum demand of the load taken by any user of electric service, although the time period over which this demand is taken has never been standardized. Two time periods, 15 and 30 minutes, and two types of meters, one measuring the arithmetic average of the load over the specified time and another in which time appears as an exponential function, are used in practice. Indications of maximum demand will be different when using the two types of meters. The first type of meter tends to cause adoption of a short time period where loads of relatively short duration, such as welding, are concerned. The second type of meter automatically recognizes the time of load duration. Adoption of a uniform time period over which maximum demand is measured is urged, based on obtaining satisfactory agreement between the readings of the two types of meters, although the differing fundamental principles make it impossible that the two types should always indicate the same values.

ELECTRICAL Equipment Used in Reflection Seismograph Prospecting, *C. C. Nash (A'33) and C. C. Palmer.* In the present-day search for petroleum, the reflection seismograph is an important and powerful tool. The reflection prospecting method measures depths to subsurface strata by recording the travel time of reflected sound waves. The acoustic energy of the sound wave is converted into electrical energy by a pickup, amplified, filtered, and recorded. The equipment, which must be rugged and portable, provides automatic gain control in the amplifier, filtering to eliminate frequencies outside the reflection spectrum, and means of recording reflections from several points on the earth's surface, together with the necessary timing mechanism. The average number of records which may be obtained in a day is about 40. From these records the folding and faulting of the various strata are mapped, and likely traps for petroleum revealed. The depths in which the geophysicist is interested range from a few hundred to as much as 20,000 feet.

SENSITIVITY of the Four-Arm Bridge, *A. C. Seletzky and L. A. Zurcher (A'38).* The rapid increase in the use of a-c bridges for the measurement of electrical and nonelectrical quantities makes desirable a critical analysis of the performance characteristics of various types of bridge structures. Selection of a particular type of bridge depends upon the requirements for sensitivity and accuracy, and the magnitude and characteristics of quantities to be measured. The unbalanced voltage appearing across the galvanometer terminals of any four-arm network can be treated as a function of the impedances of the arms in such a way as to show directly the effect of a slight change off the balance point for any of the bridge arms. Because of the wide application of amplifiers operating into null detectors, determination of sensitivity in connection with the open-circuit voltage across the galvanometer terminals has become of greater interest. A summary of sensitivity analyses of ten types of bridges shows their approach to either quadrature type or Wheatstone type for high or low values of Q.

Power Generation

MODERNIZATION of Switch-House Design, Consolidated Edison Company of New York, Inc., *A. M. de Bellis (M'33).* A program of modernization has been undertaken by the Consolidated Edison Company of New York, Inc., which serves a population of 8,000,000 in an area

of approximately 500 square miles. As a result of past experience and the advancement in the art since the various stations of the system were built, the major objective has been that of securing a greater sectionalization of the switching equipment than previously existed. Physical sectionalization has been improved by fire walls and fire doors; main busses have been sectionalized electrically, and the single-bus arrangement used in preference to the double bus which had been used more generally in the past. In one station extensive use has been made of metal-enclosed equipment, including a new type of factory-assembled metal-enclosed bus construction. Bus differential protection and high-speed relaying have been provided as additional means of localizing station faults, ventilating systems have been improved, and power-supply systems for station auxiliaries and for generator excitation have been sectionalized.

MODERNIZATION of Switch-House Design, *H. E. Strang (A'28) and W. M. Hanna (A'26).* Complete shutdown of an important generating station affects a great number of power users of all classes, and the damage can be very great physically, commercially, and politically. To improve the reliability of such a station, the possibility of the occurrence of a fault must be reduced to a minimum, the physical damage produced by a fault must be kept to a minimum, the spread of the fault must be prevented, and as far as possible an interruption of service to any consumer must be prevented. The problem involves the physical design of the apparatus and its parts, the electrical arrangement of the gear and of the system, auxiliary equipment to cure ailments if they do occur, and the co-ordination of all into one coherent whole. The modernization or construction of any large switch house should take into consideration not only the physical structure with a view to minimize faults but also system connections and auxiliary equipment with a view to prevent serious outages. Means are available to design the apparatus and system to meet successfully any set of conditions which may be encountered.

RECONSTRUCTION of Switching Facilities at Essex Generating Station, *D. W. Taylor (M'28).* Progress in protective devices by 1935 had outmoded much of the equipment of a large station of the Public Service Electric and Gas Company, and studies were started to determine the feasibility of applying modern protective schemes to the existing plant. The modernization studies were broadened to include a complete survey of the station's adaptability not only for certain immediate additions, but for future requirements. Extensive rebuilding of the 13-kv, 26-kv, and 132-kv switching facilities was necessary. In the reconstruction, no unique or unusual apparatus or design features were used. Rather, with part existing equipment, new commercially available apparatus, and refinements in standard designs of structures, a plan was developed which it is believed will provide a high order of reliability. Emphasis was placed on separation and segregation as a second line of defense to stop the spread of a conflagration.

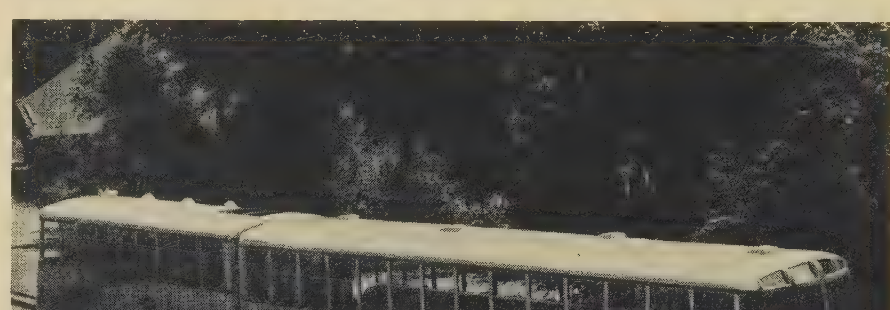
MODERNIZATION of L Street Station Switch House, Boston Edison Company, *C. A. Corney (M'20) and W. W. Edson (M'25).* Because of increased generating capacity and the addition of station ties, the calculated short-circuit fault current far exceeded the ratings of many of the oil circuit breakers in a generating station built in 1898. Modernization or replacement of the breakers would have been quite expensive. The scheme adopted called for a synchronizing bus with reactors connected to each of four bus sections, but the arrangement of busses and breakers in the switch house prevented effective application of modern principles of segregation. The necessary additional space was gained by using an unoccupied floor of the existing switch house, where small headroom introduced serious problems. In this particular installation, the masonry-cell type of construction was adopted in preference to metal-clad equipment. Along with the construction of the new switch house, there has been a considerable modernization program progressing for the rest of the station.

Power Transmission and Distribution

EQUIVALENT Circuits of Transformers and Reactors to Switching Surges, *L. V. Bewley (M'37).* The calculation of switching surges caused by circuit-breaker operations requires that transformers, reactors, generators, and other apparatus be replaced by their equivalent circuits. To be of much practical use, these equivalent circuits must be simple, as well as reasonably exact. Circuits that will react to switching in essentially the same manner as the apparatus which they replace have been obtained on a theoretical basis for reactors and several types of transformers, and their behavior compared with test results.

REGULATING Transformers in Power-System Analysis, *J. E. Hobson (A'36) and W. A. Lewis (A'27).* In the analysis of power systems, it is customary to represent generators, transformers, and transmission lines by their equivalent circuits. The resulting circuit network is solved either by representation on a network calculator, from which the solution is read directly, or analytically by successive simplification of the network. In setting up the sequence networks of systems for analysis, the common procedure is to select some one circuit voltage as a base and transfer the impedances of the various circuit elements from their actual values to equivalent values on the base voltage selected. When regulating transformers of variable ratio are involved, this process becomes confusing and difficult to follow. A straightforward approach to the problem is permitted by equivalent circuits that are set up to include ideal transformers where necessary, so that the circuit used is the exact equivalent of the actual transformer in every important respect, and may be substituted for it without making any conversions in the impedances of the other circuit elements. Then, where simplification is possible, the ideal transformers may be shifted from one location to another, until in the final diagram they may be dropped altogether.

Diesel-Electric Locomotive for Pike's Peak Railway



A RACK-RAIL Diesel-electric locomotive, said to be the first of its kind, has been built by the General Electric Company for the Manitou and Pike's Peak Railway, replacing the tilted steam locomotives used on the cog railway since its completion in 1891. Instead of hauling its load, the locomotive pushes a 50-passenger car from Manitou, Colo., at 6,562 feet elevation, to the top of Pike's Peak, 14,109 feet above sea level. The average grade is 16 per cent; the steepest 25 per cent. The new locomotive can provide traction at the wheels as well as the rack rail, but not simultaneously. It has two axles, weighs 20 tons, and is powered by three generating units, each rated 160 horsepower at an elevation of 1,800 feet. One control station is provided, and the same standard electric-drive equipment as is used in the company's new Diesel-electric industrial locomotives.

News
Of Institute and Related Activities

Summary of Local Activities Reported by Sections Committee

SECTION activities were the subject of discussion at the recent summer convention conference of officers, delegates, and members, as reported in the August issue, pages 352–3. At that time a mimeographed booklet on Section activities was distributed to the Section delegates. The booklet, which summarizes the information accumulated by the Sections committee during the past few years, has been prepared by the committee as a means of acquainting new Section officers with the types of activities found most fruitful in various Sections. The material has been accumulated since 1937, when the Sections analyzed their aims and activities (see ELECTRICAL ENGINEERING, August 1937, page 1046; March 1938, page 134; August 1938, page 351; August 1939, pages 352–3).

The following abstract of the report on Section activities, which supplements the accompanying chart, has been prepared by Chairman H. H. Race of the Sections committee. The chart has been revised since it was presented at the conference.

1. AIMS AND OBJECTIVES

Our major aim or objective as set forth in our constitution is reaffirmed:

> "The advancement of the theory and practice of electrical engineering and of the allied arts and sciences and the maintenance of a high professional standing among its members."

This was on its adoption and still is our expression of an all-time faith in a chosen work. It is the agreed-upon goal of our integrated thinking and acting and therefore the criterion by which we test our efforts.

The Sections agreed that in furthering this major objective we are also called upon continuously to recognize minor aims, which are used to guide us in conducting our daily affairs. A summary of the most frequently mentioned of these may be stated briefly as follows:

> "To provide opportunities for students and workers in the engineering field to become acquainted, to exchange ideas, to keep up to date technically, and to stimulate group activities."

Another type of minor aim, expressed in many ways, and apparently not yet clearly and definitely developed, has to do with the relation of the Section to the social group of which it is a part. Almost every Section analysis included some comment indicating interest in this question. Expressed variously it ran:

> "To inform the public"; "to promote civic interest"; "to discuss economics"; "to co-operate in promoting education"; "to stimulate the activity of engineers in community and civic interests"; and so on.

Here we note a real desire on the part of our membership to carry over into social affairs in general some of the effectiveness which has marked our activities in technical fields.

Principally through such groups as the American Engineering Council and the Engineers' Council for Professional Development, the AIEE finds at least partial facilities for maintaining contacts in general social problems. For the local Sections, however, only very limited facilities are available through which can be worked out an engineers' analysis of local, social, or civic problems for the guidance of the group as a whole or its individual members. This gives rise to our second minor aim or social objective and here it would seem that our local Section experience provides us with

AIEE SECTION ACTIVITIES

No.	67 SECTIONS	AKRON	ALABAMA	BALTIMORE *	BOSTON	CENTRAL INDIANA	CHICAGO	CINCINNATI	CLEVELAND	COLUMBUS	CONNECTICUT	DALLAS	DENVER	EAST TENNESSEE	ERIE	FLORIDA	FORT WAYNE	GEORGIA	HOUSTON	IOWA	ITHACA	KANSAS CITY	LEHIGH VALLEY
A.	MEETINGS																						
1	TECHNICAL LECTURES	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2	GENERAL INTEREST MEMBER MEETINGS	x				x	x	x	x	x	x	x	x	x			x	x				x	x
3	POPULAR PUBLIC LECTURES	x	x										x	x		x		x	x		x	x	x
4	COMBINED SECTION-BRANCH MEETINGS	x	x	x	x	x		x	x	x	x	x		x		x		x	x	x	x	x	x
5	GENERAL DISCUSSION MEETINGS							x	x														
6	SENIOR TECHNICAL DISCUSSION MEETINGS									x							x				x		x
7	JUNIOR TECHNICAL DISCUSSION MEETINGS																						
8	PRIZE PAPER CONTESTS			x				x					x				x			x			
B.	EDUCATIONAL ACTIVITIES																						
9	TECHNICAL STUDY COURSES									x	x												
10	EDUCATIONAL SERVICE TO SECONDARY SCHOOLS		x					x	x							x	x						
11	PAPERS BY MEMBERS							x						x									x
C.	PROMOTIONAL ACTIVITIES																						
12	SOCIAL AFFAIRS	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x
13	COOPERATION WITH OTHER ENGINEERING SOCIETIES	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
14	NEWS LETTERS AND BULLETINS										x			x					x				
15	INSPECTION TRIPS			x	x			x	x		x		x	x					x		x		x
16	LOCAL TECHNICAL SUBCOMMITTEES						x																

No.	67 SECTIONS	LOS ANGELES	LOUISVILLE	LYNN	MADISON	MANSFIELD	MEMPHIS	MEXICO	MICHIGAN	MILWAUKEE	MINNESOTA	MONTANA	MUSCLE SHOALS	NEBRASKA	NEW ORLEANS	NEW YORK	NIAGARA FRONTIER	NORTH CAROLINA	OKLAHOMA CITY	PHILADELPHIA	PITTSBURGH	PITTSFIELD	PORTLAND
A.	MEETINGS																						
1	TECHNICAL LECTURES	x	x	x	x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x
2	GENERAL INTEREST MEMBER MEETINGS		x		x	x	x		x								x	x	x	x	x		x
3	POPULAR PUBLIC LECTURES		x	x	x		x			x			x			x		x				x	
4	COMBINED SECTION-BRANCH MEETINGS	x	x		x						x		x	x	x	x		x	x	x	x		x
5	GENERAL DISCUSSION MEETINGS				x	x	x			x													
6	SENIOR TECHNICAL DISCUSSION MEETINGS																			x	x	x	
7	JUNIOR TECHNICAL DISCUSSION MEETINGS								x													x	
8	PRIZE PAPER CONTESTS	x		x							x									x	x	x	x
B.	EDUCATIONAL ACTIVITIES																						
9	TECHNICAL STUDY COURSES															x				x	x	x	x
10	EDUCATIONAL SERVICE TO SECONDARY SCHOOLS					x			x	x												x	
11	PAPERS BY MEMBERS	x		x			x								x				x				
C.	PROMOTIONAL ACTIVITIES																						
12	SOCIAL AFFAIRS	x	x	x	x	x	x			x	x		x		x	x	x	x	x	x	x	x	x
13	COOPERATION WITH OTHER ENGINEERING SOCIETIES	x	x	x	x	x	x		x	x	x		x	x	x		x	x		x	x		x
14	NEWS LETTERS AND BULLETINS			x			x		x				x						x			x	
15	INSPECTION TRIPS	x	x	x	x	x	x		x	x			x	x	x	x	x	x	x	x	x		x
16	LOCAL TECHNICAL SUBCOMMITTEES			x												x							x

No.	67 SECTIONS	PROVIDENCE	ROCHESTER	ST. LOUIS	SAN ANTONIO	SAN DIEGO	SAN FRANCISCO	SASKATCHEWAN	SCHENECTADY	SEATTLE	SHARON	SPOKANE	SPRINGFIELD	SYRACUSE	TOLEDO	TORONTO	TULSA	URBANA	UTAH	VANCOUVER	VIRGINIA	WASHINGTON	WICHITA	WORCESTER	PER CENT PARTICIPATION
A.	MEETINGS																								
1	TECHNICAL LECTURES	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	97
2	GENERAL INTEREST MEMBER MEETINGS		x		x	x			x			x	x		x	x	x	x	x			x		x	55
3	POPULAR PUBLIC LECTURES								x		x			x	x			x						x	37
4	COMBINED SECTION-BRANCH MEETINGS			x	x				x	x		x				x	x	x	x	x	x	x	x	x	67
5	GENERAL DISCUSSION MEETINGS	x													x								x		12
6	SENIOR TECHNICAL DISCUSSION MEETINGS	x	x				x		x	x	x					x									21
7	JUNIOR TECHNICAL DISCUSSION MEETINGS	x							x																6
8	PRIZE PAPER CONTESTS				x		x		x	x			x			x	x	x				x	x		33
B.	EDUCATIONAL ACTIVITIES																								
9	TECHNICAL STUDY COURSES	x							x				x							x					16
10	EDUCATIONAL SERVICE TO SECONDARY SCHOOLS		x													x		x				x			19
11	PAPERS BY MEMBERS																x					x			13
C.	PROMOTIONAL ACTIVITIES																								
12	SOCIAL AFFAIRS	x	x	x	x	x		x	x		x	x			x	x				x		x	x	x	79
13	COOPERATION WITH OTHER ENGINEERING SOCIETIES	x	x			x	x	x	x	x	x	x	x	x					x			x	x	x	79
14	NEWS LETTERS AND BULLETINS		x				x																		16
15	INSPECTION TRIPS	x	x			x				x	x				x	x	x		x	x		x	x		60
16	LOCAL TECHNICAL SUBCOMMITTEES		x						x													x			10

* NOW MARYLAND SECTION

9-12-39

little guidance. However, this problem is quite likely the outstanding one of our time.

"We are not at loss as to our objectives in connection with it. We want to *preserve*, *protect*, *regain*, and *build* a social environment which will permit us to work for the advancement of the theory and practice of electrical engineering and of the allied arts and sciences and the maintenance of a high professional standard among our members."

Many local Sections want to do something about this. Insofar as such activities are constructive, this work is well within the scope of our objectives. In bringing to social problems the engineer's way of thinking, three aims are realized. First, these problems invariably have technical phases which lend themselves to correct solutions only through objective treatment. To this extent, therefore, science is advanced. Second, a high professional standard among engineers is realized only when co-operation and not isolation is the program. Third, the privilege of pursuance of our major objective requires a vigilant attitude toward the changing social structure, lest we find ourselves within an environment which considers our activities and aims unimportant.

2. Activities

The accompanying chart summarizes the results of the surveys conducted during the past three years. The activities of the different Sections are extremely varied because of great differences in their size, location, and personnel.

The technical activities of most Sections are well organized. However, in addition, where they are not already doing so, the Section officers are urged to enlarge the scope of their activities in the following ways:

A. Take an active interest in young men before and immediately after they enter the profession: (*a*) through educational activities in secondary schools, (*b*) by sponsoring joint meetings with neighboring Branches, (*c*) by scheduling younger member and inter-Section prize-paper contests, and (*d*) by encouraging active participation in the Sections committee work.

B. Implement the engineer's desire for group activity in influencing social conditions: (*a*) by co-operation with other local engineering societies, (*b*) by approving or suggesting improvements in the AIEE model registration law (see page 354 of the August issue), (*c*) by continuously keeping informed regarding proposed legislation likely to affect electrical engineers, (*d*) by stimulating and organizing social and economic studies and discussions in local groups and by exerting influence in local affairs where engineering analysis can be advantageously employed, and (*e*) by expressing the engineer's reactions to national social and economic problems to and through the American Engineering Council.

Membership—

Mr. Institute Member:

"A substantial increase in the representation of each locality in the Institute" is the objective of the membership committee in its plans for the 1939–40 season. As in earlier years, the committee is counting upon the assistance of the individual member through the proposal of names of desirable candidates for admission; a communication on this subject will be issued shortly to the entire membership.

Qualified new members are essential to the health and growth of the Institute. Your prompt co-operation will be both helpful and highly appreciated.

Chairman, National Membership Committee

Charles F. Scott Honored by Connecticut Section

In consideration of "the accomplishments to his credit in the engineering field and his services to countless engineering organizations and the humanities," the AIEE Connecticut Section held a testimonial dinner for Doctor Charles F. Scott, September 19, 1939, on the occasion of his seventy-fifth birthday anniversary. The gathering was held at the New Haven Lawn Club, close by Yale University where Doctor Scott's name has been a byword since 1911. Some 150-odd were present to pay homage to the fifteenth president of the AIEE, many from points far outside the state.

Toastmaster was Past-President Frank B. Jewett who characterized Doctor Scott as one who more than any other single individual had constructively influenced American engineering during the past quarter-century. Speakers included President Farmer and Past-Director C. E. Stephens of the AIEE, President-Emeritus Angell of Yale University, and Former-Governor Cross of Connecticut. Presiding at the dinner meeting was Chairman R. S. Judd, and heading the general committee was Past-Chairman R. G. Warner, both of the Connecticut Section.

NRC Insulation Conference to Meet in Cambridge, Mass.

The twelfth annual meeting of the conference on electrical insulation of the division of engineering and industrial research, National Research Council, will be held at Harvard University, Cambridge, Mass., November 2–4, 1939.

According to the tentative program, the first day will be devoted to chemistry, physics, and measurements, and the second to properties of dielectrics, including insulation of high-voltage cables. The program for the third day has not yet been finally determined. The tentative program is expected to include about 25 papers. Presentation of papers will be brief, to allow for adequate discussion.

The conference will continue its usual practice of having presented unpublished researches and progress reports. The only record of the meeting will be a series of short abstracts of the papers presented, although it is expected that most of the material offered will eventually appear in finished form in various scientific and engineering publications.

Because of recent illness, Doctor J. B. Whitehead (A'00, F'12) of Johns Hopkins University, chairman of the conference throughout most of its history, has resigned that post. His successor has not yet been appointed. In the interim, arrangements for the coming meeting are being made by W. A. Del Mar (A'06, F'20) Habirshaw Cable and Wire division, Phelps Dodge Copper Products Corporation, vice-chairman; W. F. Davidson (A'14, F'26) Consolidated Edison Company of New York, Inc., secretary; and C. L. Dawes (A'12, F'35) electrical-engineering department, Harvard University, who is representing the University and arranging the social aspects of the conference, as well as visits to laboratories.

Temperature Symposium to Be Held in New York

A symposium on the measurement and control of temperature in science and industry will be held in New York, N. Y., November 2 to 4, 1939, by the American Institute of Physics, with the co-operation of the National Bureau of Standards, the National

Future AIEE Meetings

Middle Eastern District Meeting
Scranton, Pa., October 11–13, 1939

Winter Convention
New York, N.Y., January 22–26, 1940

Summer Convention
Swampscott, Mass., June 24–28, 1940

Pacific Coast Convention
Place and date to be announced.

Research Council, and officers and committees of many technical societies. Preliminary announcement of the meeting appeared in the April issue, page 180.

The program is in charge of representative committees of authorities in various fields, who have arranged for 100 or more papers on scientific and technical subjects, to be presented in concurrent sessions of selected groups. All interested persons active in science or engineering are cordially invited to attend the sessions, and take part in the discussions of papers. A complete program containing full abstracts of the papers to be presented will be mailed in advance on request to the Institute. It is suggested that those who expect to attend will inform the Institute (175 Fifth Avenue, New York, N. Y.) and make their hotel reservations early. Registration fee will be $1.00.

World's Largest Hydro Plant Now at Boulder Dam

The power plant operating at Boulder Dam is now the largest of its kind, since its seventh large generator has gone into steady operation, according to *The Reclamation Era* (August, 1938, page 193). The seven large units and one smaller unit give the plant a capacity of 860,000 horsepower. The Dnieprostroy plant in Russia, previously the largest hydroelectric power plant has a capacity of 746,000 horsepower.

The ultimate capacity of the Boulder Dam plant is 1,835,000 horsepower. It will eventually house 15 large generators, rated at 82,500 kva each, and 2 small ones, rated at 40,000 kva each. Another large generator is expected to be ready to go into steady service about October 1, and two more are now being manufactured. The generator most recently placed in operation was hurried to completion to prevent a prospective power shortage in the system of the Southern California Edison Company, which it serves.

Public-Utility Accident Rates for 1938

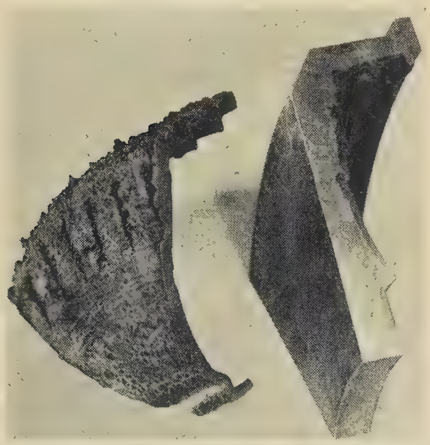
The National Safety Council's annual statistical report on accident rates in public-utility companies during 1938 shows 11.37 injuries per million man-hours of exposure and 1.97 days lost per thousand man-hours of exposure. The first, or frequency rate, is 16 per cent lower than in 1937, and the second, or severity rate, 1 per cent lower. The average frequency rate for all industries is 12.18; the average severity rate 1.53.

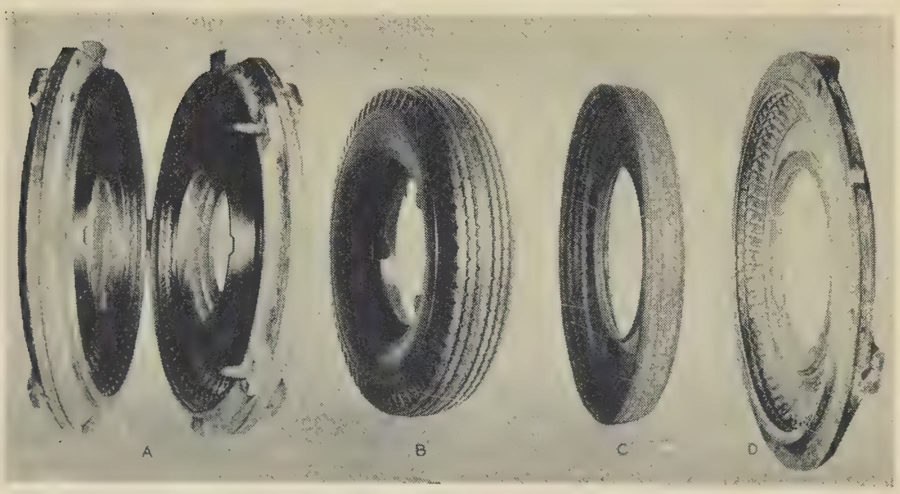
While large organizations within the industry had lower injury rates, the showing of small companies improved more over 1937 than did the average for the industry. Telephone and telegraph companies continued, as in the past, to have the lowest injury rates, averaging 4.40 for frequency and 0.14 for severity during 1938; these companies also showed the largest decrease in frequency since 1937, 21 per cent. Manufactured-gas companies made the largest decrease in severity, 40 per cent.

The commonest accident cause, reported in 119 fatalities and permanent partial disabilities was unnecessary exposure to danger. Accidents resulted from entering areas rendered unsafe by electrical or other haz-

Molds Produced by Electroforming With Iron

IN A series of demonstration lectures before groups of technical and trade publication editors, the United States Rubber Company recently described its "Ekko" process for the preparation of molds and dies by electroforming iron against a pattern. Electroforming is essentially a long-time electroplating process in which deposits up to one-half-inch thick are produced when heavy electroformed deposits of iron are separated from the underlying pattern, a cavity or die insert is obtained which has reproduced the shape and surface finish of the pattern in every detail. When properly mounted, this cavity or die may be used to mold or stamp objects that are exact duplicates of the original pattern. Although developed originally for producing automobile-tire molds, the process is now being used in the making of dies and molds for the plastics, glass, embossing, and metal stamping industries. The accompanying illustration shows: (*A*) A mold made by the usual process of engraving in which the tread design and cavity are cut out of a steel forging with special engraving machines; (*B*) rubber tire pattern ready for duplication by the Ekko process; (*C*) half of the resulting electroformed mold; and (*D*) electroformed mold fitted into "the watch case" back. The cross sectional close-up view shows how the metal is deposited into the pattern and the roughness that is characteristic of heavy electro deposits. A heated electrolyte is used in the process, and a period of 21 days is required to produce a complete tire mold. The iron produced by this process is said to be 99.98 per cent pure and substantially free from porosity; it is also about 50 per cent harder than cold rolled steel and has a heat conductivity nearly twice that of cast iron or steel.





Exposition Illumination Reprints Available

A small supply of pamphlets containing the 16-page special article published in the June 1939 issue of Electrical Engineering on the remarkably effective decorative illumination characterizing the San Francisco-Golden Gate International Exposition is now available to members and subscribers at the special price of 25¢ each postpaid. The pamphlet, 16 pages and cover $8^1/_2$ by 11 inches in size, is printed on the same heavy special stock that was used in the June issue and includes all of the large and remarkably true-to-life four-color illustrations, together with the explanatory text and supplementary diagrams of equipment installation. Within the limits of available stock, orders will be filled in the order of their receipt.

Orders, together with 25¢ in cash or stamps, should be sent to AIEE Order Department, 33 West 39th Street, New York, N. Y., with sender's name and mailing address typewritten or printed in the interest of satisfactory delivery.

ards, standing under suspended loads, working on high-voltage conductors from above instead of from below, and gripping, holding, or lifting objects improperly. Chief mechanical cause was improper guarding.

The 1938 experience of the public-utility industry was compiled from reports of 625 companies whose employees worked 699,135,000 man-hours during the year. Of 30 major industries surveyed, public utilities ranked 16th in frequency of accidents, and 24th in severity. Since 1926, public utilities have decreased frequency rates 79 per cent, compared with a 68-per cent reduction for all industries, and severity rates 65 per cent, compared with 44 per cent.

National Safety Council reports on accident rates, which are issued for 24 industries and industry groups, are based chiefly on the records of members of the Council, although nonmembers are included in some cases. Information is compiled in accordance with standard definitions, and reports are identified by key numbers known only to the Council and the individual company.

Bakelite Corp. Bought by Union Carbide and Carbon

A further significant step in the trend toward integration in the plastics industry was taken August 29 when the Union Carbide and Carbon Corporation acquired all the assets of the Bakelite Corporation.

In commenting on this deal, *Business Week* indicates the significance of this move to the plastics industry by recalling the consolidations that began in the steel industry in the 90's and more recently in the automotive industry, with the emergence of the so-called "big three," Union Carbide previously had been supplying Bakelite with a large share of basic chemicals and materials, and the combined facilities seem to bring Union Carbide to the front along with Du Pont and Monsanto as the "big three" in plastics. New alignments are expected among the several competitive suppliers of plastic materials, which include General Electric and Westinghouse.

Chemical Exposition. The 17th Exposition of Chemical Industries will be held at Grand Central Palace, New York, N. Y., December 4–9. Exhibits will feature unit processes of chemical engineering, as well as equipment and product developments in industries which are chemical in nature, or chemically influenced or controlled. The student course in chemical engineering which has been a part of previous expositions will be offered again this year. Founded in 1915, the Exposition is now established on a biennial basis.

Principles of Naval Architecture. The Society of Naval Architects and Marine Engineers has announced the publication of a two-volume reference work, "Principles of Naval Architecture," intended to meet the need for a comprehensive modern text for students, naval architects, and marine engineers, as well as executives and others interested in the operation and maintenance of vessels. Written by a group of authorities, the two volumes were supervised by a control committee of the Society. Copies may be obtained from the Society of Naval Architects and Marine Engineers, 29 West 39th Street, New York, N. Y.; price $11 for the set.

American Engineering Council

War Plans to Be Studied By Civilian Board

With the approval of President Roosevelt, the Army and Navy have formed a War Resources Board, composed of six civilians prominent in industrial life, who will immediately review the comprehensive plans prepared over a period of years by the military authorities for the mobilization of industrial supplies in case of war.

Named to the new Board were Edward R. Stettinius, Jr., president of the United States Steel Corporation; Doctor Karl T. Compton (F'31), president, Massachusetts Institute of Technology; Walter S. Gifford (A'16), president, American Telephone and Telegraph Company; Dr. Harold G. Moulton, president, The Brookings Institution; John Lee Pratt, General Motors Corporation; and General Robert E. Wood, Sears, Roebuck and Company.

Immediately after the appointments were announced the Board convened in Washington to begin its work, and several meetings were held to acquaint the members with all details of present plans for industrial mobilization. After giving these thorough consideration it is expected that the Board will submit a report making suggestions, if necessary, for further refinements.

Experience from the Council of National Defense, headed by Walter S. Gifford in 1917, is available to the new board through his membership. It is assumed that the War Industries' Board, now an advisory arm of the Army and Navy Munitions Board, in the event of war would become a War Resources Administration reporting directly to the President. Presumably, it would attempt to co-ordinate the economy of the country with particular attention to the munitions requirements of the Army services and should war come, it would be assumed that these requirements for munitions would be co-ordinated with the needs of the civilian population.

Information at the office of the War Resources Board indicates that should a wartime industrial mobilization be necessary, it would revolve around the War Resources Administration, but that the actual administration of various activities would be in the hands of the regular agencies handling them or with new agencies.

Effective instrumentalities developed in the twenty-two years that have passed since the last war are the trade and technical associations. Practically all the industries are highly organized and are in possession of statistical and other information which can be quickly put at the disposition of a War Resources Administration.

Future Meetings of Other Societies

American Institute of Physics. Temperature symposium, November 2–4, New York, N. Y.

American Physical Society. 230th meeting, December 1–2, Chicago, Ill.

231st meeting, December.

Annual meeting (232d), December 28–30, Columbus, Ohio.

American Society of Heating and Ventilating Engineers. 46th annual meeting, January, 1940, Cleveland, Ohio.

American Society of Mechanical Engineers. Annual meeting, December 4–8, Philadelphia, Pa.

Conference on Electrical Insulation (National Research Council). November 2–3, Cambridge, Mass.

Institute of Radio Engineers. Fall meeting, November 13–15, Rochester, N. Y.

National Electrical Manufacturers Association. October 23–27, Chicago, Ill.

National Safety Council. October 16–20, Atlantic City, N. J.

Société Française des Électriciens. Television meeting, November, Paris, France.

Standards

Co-ordinating Committee 3 Announces Projects

When the AIEE standards committee organized sub-groups for special work (see May issue, pages 222–3) co-ordinating committee 3 was assigned the problem of reviewing the subject of insulation testing in electrical machines and the co-ordination of investigations of new tests for the evaluation of insulation in service.

The personnel of committee 3 is to be made up of engineers primarily interested in insulation. To date the following have accepted membership:

C. F. Hill, Westinghouse Electric & Manufacturing Company, *chairman*
J. S. Askey, Westinghouse Electric & Manufacturing Company
W. B. Kouwenhoven, Johns Hopkins University.
S. H. Mortensen, Allis-Chalmers Manufacturing Company
H. R. Stewart, New England Power Service Company
J. B. Swering, Hartford Steam Boiler Inspection and Insurance Company
R. L. Webb, Consolidated Edison Company of New York, Inc.
R. W. Wieseman, General Electric Company

A review of present standards seems desirable at this time to determine if they are consistent with experience and developments since their adoption some years ago. Test procedures in foreign countries will also be reviewed and compared with American practice.

A second project recognizes the efforts of the users of electrical machinery to evaluate insulation in service and proposes to co-ordinate the efforts of other interested engi-

neering groups toward a more general solution of this problem, with final standardization, if possible.

Session on Standards at Scranton Meeting

In continuation of the symposium on rating held at the AIEE winter convention last January, a further discussion of rating and associated standards problems will be held on October 11, during the Middle Eastern District Meeting, Scranton, Pa., under the auspices of co-ordinating committee 4 of the standards committee.

Four papers will be presented. One of these will deal with the effect of solar radiation on temperature rise of apparatus, and another with the operating conditions affecting electrical apparatus met with in the steel industry. These two papers supplement the paper on weather conditions affecting electrical apparatus presented at the San Francisco convention, placing on record a general review of the ambient temperature and air conditions under which electrical apparatus operates.

The two other papers will deal with the rating and application of d-c motors and of distribution transformers, respectively, under conditions of variable load cycles. These papers point out design factors and insulation requirements which affect the selection of apparatus for use under variable load conditions, and supplement the similar information presented on induction motors at the January symposium.

Following the presentation of these four papers, an informal report will be presented by co-ordinating committee 4, which has been charged with the responsibility of revising AIEE Standard No. 1, dealing with the "General Principles Upon Which Temperature Limits Are Based in the Rating of Electrical Machinery and Apparatus." A meeting of this committee will be held in the morning preceding the technical session, and it is hoped that at that time reasonably complete agreement will be reached on a draft revision of this standard. An open discussion of this and other standards activities will be held following the presentation of the informal committee report.

The purpose of undertaking this revision of the AIEE Standard No. 1, which has not been changed since 1925, is to take into account the numerous changes in the various standards for specific types of apparatus which have been made since that time, and to assure a continuing sound basis for the further development of the American system of electrical-apparatus rating.

Standard No. 1 deals with the general considerations upon which temperature limits of rating are based, and does not embody rules or limits for testing any specific type of apparatus. It establishes general principles with respect to temperature rise for the guidance of those responsible for the preparation of specific standards, and serves as an introductory chapter to the standards of the AIEE. Its especial purposes are to promote consistency between the various American and international standards for electrical apparatus, and to facilitate the understanding of differences in rating limits where these exist.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or reject them entirely.

ALL letters submitted for consideration should be the original typewritten copy, double spaced. Any illustrations submitted should be in duplicate, one copy to be an inked drawing but without lettering, and the other to be lettered. Captions should be furnished for all illustrations.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

A Substitute for "Susceptance"

To the Editor:

In Group 05, Section 20, of the Proposed American Standard Definitions of Electrical Terms, sponsored by the Institute, are definitions for six ratios among the components of voltage and current between two points in an electric circuit: impedance and admittance, resistance and conductance, reactance and susceptance. In each of the first two pairs, the two terms have a similar significance and connotation, including that of their mutually reciprocal nature. In the last pair, however, the two terms are quite different in derivation and connotation.

It is interesting to note that the AIEE TRANSACTIONS (volumes 10 and 11, 1893 and 1894) of the days when complex quantities were first being applied to the computation of a-c circuits record prolonged discussions over the choice between "reactance" and "inductance" to designate the ratio of quadrature voltage drop to current. On the other hand, "susceptance" seems to have been adopted with hardly the suggestion of an alternative name. To open up the question at the present time may seem more academic than practical, but if a more appropriate term can be found, it would appear advisable at least to consider it. Terminology is not necessarily fixed or static; witness the comparatively recent displacement of the term "capacity" by "capacitance," and the still more recent change in application of the term "oersted."

The present definitions for reactance and susceptance depend upon the relative values of quadrature components of voltage and current, respectively, regardless of the means by which the phase displacements giving rise to these quadrature components may be brought about. Actually, the application of the two terms is confined largely, if not exclusively, to those displacements which result from the magnetic and electric fields associated only with the partial circuit question.

"Permeability" designates a certain magnetic characteristic of any medium. "Inductance" designates a magnetic characteristic of an electric circuit linking one or more magnetic media; the value of the coefficient of inductance depends upon the permeability of the media and the dimensions of the circuit. "Reactance" designates the ratio of that portion of the voltage reaction of a circuit which is due to its magnetic characteristics, to the alternating current causing this reaction; the value of this ratio depends upon the inductance of the circuit and the frequency of the current.

"Susceptibility" also designates a certain magnetic characteristic of any medium, and it is related to permeability in a linear manner. By an interchange of suffixes, this term is converted into "susceptance," which has been applied to the ratio of the quadrature component of current between two points in a circuit to the alternating voltage across them.

The logic and propriety of such a procedure is open to question on two grounds. First, it is entirely out of line with the steps which lead up to the term "reactance," as just outlined. It is true that "permeability," by a similar interchange of suffixes is sometimes converted into "permeance," but that term is confined to the magnetic circuit, where its significance is analogous to that of conductance in the electric circuit.

Second, the relation of capacitance to a quadrature current component is as simple and direct as that of inductance to a quadrature voltage component. Conversely, the relation of inductance to a quadrature current component is as involved as the relation of capacitance to a quadrature voltage component. Since the simple relation has been adopted for the quadrature voltage component, the relation of quadrature current component to applied voltage should be described in terms equally elementary. It therefore seems inappropriate to base a designation for this ratio upon the name of a magnetic characteristic of a medium.

While the ratio denoted by "reactance" is properly considered as a reaction, an electric current is more commonly regarded as an action that results directly from, or occurs with, the application of a potential difference or voltage. A term which conveys the idea can be obtained by substituting for the prefix "re-" one which means "with," as "con-" or "co-"; the alternative forms *conactance* or *coactance* result, either of which is a more truly descriptive name than "susceptance," is shorter by one or two letters, and has an interesting mnemonic feature. Impedance is now composed of resistance and reactance, and if the new term were adopted, admittance would be composed of conductance and *co(n)actance.*

As a teacher of electrical subjects, the writer has for many years sought the most fundamental and widely used relationships, in order that the new and discrete concepts which the students are required to master may be as few in number and broad in

application as possible. It is this aim which motivates this questioning of the old term "susceptance," because it is believed that a more significant word will assist in clearing up what might be called one of the minor "untidinesses of the electromagnetic theory" referred to by Professor Synge at the 1937 convention of the Society for the Promotion of Engineering Education, in Cambridge, Mass.

The usual procedure is to introduce the students to resistance, inductance, and capacitance as independent concepts, the two latter manifesting themselves only when the current or voltage is changed in magnitude. When periodic changes are considered, it is demonstrated (by maintaining at a constant magnitude the current through an inductive coil, as measured by, say, a dynamometer instrument, and noting that a much higher applied voltage is required for alternating current than for direct), that alternating current generates a voltage reaction not produced by direct current. It then develops that much the greater part of this additional voltage reaction has a quadrature relation to the voltage reaction of the coil resistance, and, like the latter reaction, is proportional to the alternating current; the new proportionality factor is called reactance and is equal to the product of the coil inductance and an angular velocity corresponding to the frequency. The relationship of the total alternating voltage to the current is symbolized by the equation

$$\frac{\dot{E}}{\dot{I}} = Z = R + jX = R + j\omega L$$

This state of affairs is somewhat puzzling and its mastery is usually somewhat complicated and delayed by the introduction of another circuit constant, capacitance. By treatment that is usually analytical, rather than experimental, it is pointed out that the voltage reaction due to this new circuit element is also in quadrature with the voltage reaction due to resistance, and at the same time, opposite in phase to the voltage reaction due to inductance, and proportional, not to the capacitance, but to the reciprocal of the product of the capacitance and the angular velocity. Symbolically, this new reactance

$$-X_e = -1/(\omega C)$$

This method of handling capacitance produces in the mind of the thoughtful student many troublesome questions, some of which may require a long experience for a satisfactory answer. In the first place, there is the matter of the reciprocal itself; that, however, is a definite thing, susceptible of analytical proof, and can be utilized by rote, without complete comprehension.

The second question relates to resistance. The student comprehends the resistance of the coil and of the rest of the circuit and realizes that it must properly be considered as part of the coil impedance. But he also remembers that, by virtue of its construction, a capacitor is virtually an open circuit and therefore of infinite resistance, although little or no account of this resistance is taken in considering the voltage reaction of a capacitor. His confusion is not diminished when he comes to take the reciprocal of his impedance and finds that he cannot take the reciprocal of his reactance directly, and write $1/(\omega L)$, but must go through a process of inversion and rationalization which gives even the relatively small resistance of the coil a counterpart in the resulting admittance.

Sooner or later the student will have to do with a capacitance in which the losses are not negligible, and then he will learn that $1/(\omega C)$ is sometimes no more correct for the value of an elastive reactance than $1/(\omega L)$ is for a susceptive *co(n)actance*. Then he may realize that the reason it has been possible to state

$$X_e = -1/(\omega C)$$

as a fundamental relationship is the fortuitous circumstance that the frequencies, flux densities, and construction materials in common use hitherto have been such that the energy losses in a capacitor have generally been negligible, while the losses in a coil are usually considerable.

With the commercial development of capacitors of relatively large capacitance, and the use of higher frequencies, it would seem the time has come to develop a general treatment of capacitance co-ordinate with that given to inductance; that is, let the fundamental case include the losses, with the special case resulting from the circumstance that the losses may be negligible treated as a simplification of the general case.

Consider how closely such a fundamental treatment may be made to follow, but with a characteristic distinction, the procedure by which the components of impedance are derived. It may be demonstrated (by maintaining at a constant magnitude the *voltage across* a capacitance, as measured by, say, a dynamometer instrument, and noting that a very much greater *current* results from an alternating *voltage* than from a constant unidirectional voltage) that an alternating *voltage* generates a current component not produced by a constant rectified *voltage*. It may then be developed that much the greater part of this additional *current* has a quadrature relation to the conductance *current* of the capacitor, and, like the latter component, is proportional to the alternating voltage; the new proportionality factor may be called *co(n)actance* and is equal to the product of the capacitor capacitance and the angular velocity corresponding to the frequency. The relationship of the total alternating *current* to the *voltage* is symbolized by the equation

$$\frac{\dot{I}}{\dot{E}} = Y = G + jB = G + j\omega C$$

Thus we have the co-ordinate and fundamental relationships; in both of which, be it noted, the quadrature component is positive:

1. (Inductive) Impedance is composed of resistance and (inductive) reactance.

2. (Capacitive) Admittance is composed of conductance and (capacitive) *co(n)actance*.

These but paraphrase Doctor Steinmetz's statement of some years ago that the four fundamental constants of an electric circuit are resistance, reactance, conductance, and susceptance.

An impedance and an admittance cannot be combined with each other except by the process of inversion and rationalization. This step then becomes associated equally with the handling of either impedance or admittance, and is to be regarded as a normal and expected procedure to be mastered, instead of a tedious expedient to be avoided.

Even with the possible adoption of a term like *co(n)actance*, "susceptance" could still be given a useful place in the terminology by using it with reference to inductance, much as elastance is used with reference to capacitance.

Then, in addition to the fundamental impedance and admittance concepts, there are two secondary concepts derived by inversion:

Elastive impedance, composed of elastive resistance and elastive reactance,

$$Z_e = \frac{1}{Y} = \frac{G}{Y^2} - j\frac{B}{Y^2} = R_e - jX_e$$

and susceptive admittance, composed of susceptive conductance and susceptive *co(n)actance*,

$$Y_e = \frac{1}{Z} = \frac{R}{Z^2} - j\frac{X}{Z^2} = G_s - jB_s$$

Of course, any of the four constants which do not appear in one of the fundamental equations will have no counterpart in the respective derived equation. Hence for special conditions it would still be true that

$$X_e = -1/(\omega C)$$

In view of these considerations it is suggested that the question of a more significant name for the ratio now designated by "susceptance" be taken under consideration by the proper committee of the Institute.

Yours very truly,

A. A. Nims (A'11, M'28)

(Professor of electrical engineering, Newark College of Engineering, Newark, N. J.)

Graduate Training for Engineers

To the Editor:

It is very gratifying to one who has given much thought to the subject of education for engineers to note that at least one branch is receiving serious consideration. The general trend of electrical-engineering development makes it imperative to give the matter most serious consideration. The article entitled "Graduate Training for Engineers" lays down the general problem most capably but I disagree with the proposition put forward that the solution to the problem of training men having "the ability to do new and difficult feats in industry" is to be found in postgraduate training.

The principle of producing an article capable of general application and then modifying it to do a specific function is bad engineering practice, so why should one apply such an evil principle to the most vital function of engineering—the training of its personnel. The opinion of administrative heads of firms that postgraduate training is a waste of time is well founded on their engineering instincts. If there is any correcting to be done, they prefer to do it themselves.

A point which I consider has not been properly considered in the past is that engineers may be divided into three broad cate-

gories, namely: development engineers, applicational engineers, and operational engineers.

A development engineer is one whose function is to advance his particular branch of engineering by the development of new materials and equipment—in fact one who stands on the borderline between pure science and engineering.

The applicational engineer is an engineer proper with a bent in a particular direction —that of applying the products of his branch to the use of mankind. The work carried on by such an engineer includes what is commonly known as design work in engineering manufacture, or the activities of sales engineer (as distinct from a salesman) applying his equipment to the various functions required.

An operational engineer is one who controls the generation and distribution of electricity or the manufacture of electrical products.

The educational and training requirements for the three branches are, I submit, entirely different and I consider a great deal of time, valuable energy, and money is wasted in trying to provide a curriculum that will turn out engineers suitable for any of the three.

The attainments of most men are governed by their environment. Thus a development engineer must be so educated that he numbers amongst his acquaintances scientists; an operational or an applicational engineer must be so educated as to number amongst his acquaintances development engineers. For this purpose I support the creation of technological colleges, but not with quite the same aim as Mr. Morrow.

The major tool in the equipment of any engineer embarking on advanced development is mathematics, followed at a distance by a comprehensive knowledge of chemistry and physics. The aspirant to the position of development engineer must, therefore, show an exceptional aptitude for mathematics. If in completing his secondary-school studies to the standard of the matriculation examination of the University of London the boy shows ability in mathematics and wishes to become an engineer, he should be given an opportunity of going to a university where his graduate study should be mathematics to a very high standard—not less than the mathematical tripos of Cambridge University, with physics and chemistry as secondary subjects.

He could then take his engineering as a postgraduate course at a technical college, this training being followed by two years of actual work as an apprentice in an engineering works. Thus, for the most advanced branch of engineering, I advocate the postgraduate training of a mathematician in engineering, and not vice versa. My reasons for this are: first, experimental results, that is, I have met young men who have been correctly guided into taking this course and the result is brilliant. The explanation is of course quite simple, in that the principles of engineering are relatively simple, but the mathematical working-out is not always easy. While the normal student is struggling to understand the mathematical steps, the mathematical graduate sees the result in advance and can concentrate on the principles and the implications of the result. The second is my experience in coaching both types of students, where the contrast cited simply "hits one in the face."

I agree with Mr. Morrow that it is not necessary for manufacturers to offer any specific inducement to engineers with high training as, if they have the personality to apply their training, they will rise to the highest positions by their own natural "development potential."

The applicational engineer is of different type. His major requirement is quickness of thought and breadth of vision, since it is he who to a great extent sets the problems for the development engineer. I personally do not consider that a university education, as it is understood in England, is essential to the applicational engineer. The training should be given by a technical college where development engineers are taking their postgraduate course. The latter could assist the faculty and gain valuable training themselves by taking junior classes in mathematics, physics, and chemistry. The training should be carried out in conjunction with an engineering works. Thus on leaving a secondary school, that is, having knowledge to the London University matriculation standard, the student should be put for a year into an engineering works with the insistence that he attend evening classes to continue his studies. It should be possible for him during this year to attain the standard of the intermediate examination for external students of the London University. If possible, arrangements should be made with the works to allow the student one day per week to attend at the college all day, and he should be retained by the firm until he has passed his intermediate examination, say up to a maximum of two years. Having passed his intermediate examination and having seen from his engineering shop training the object of his future studies, the student should be given two years full-time technical training at the technical college, culminating in an examination to the standard of the honours degree in engineering of the London University. This should then be followed by two years in an engineering works.

The result of such a training will be that the graduate will have a very thorough foundation in engineering and will have sufficient mathematical and scientific knowledge to understand the language talked by the development engineers, but he will have a much wider practical knowledge and will think in terms of machines. If he is an electrical engineer, he will be capable of interpreting the requirements of mechanical drives into electrical specifications and will be able to select the correct equipment for a given duty and indicate to the development engineer where there are gaps in the equipment available.

It is possible and highly desirable to give postgraduate training to this type of engineer but this must follow, not precede, the two years of apprenticeship. It is very difficult to know how this postgraduate training, preferably in economics, industrial administration, and his own specialty, can be given. The only solution is some form of evening lectures, but these are not very successful in so far as I have been able to observe, since after having worked hard for many years, the young man feels it is time he had some time to himself to take an interest in world affairs and what I euphemistically call the humanities.

The operational engineer is required to handle men and apart from the actual production of commodities, his contribution to the general weal is to prevent industrial strife. To do this he must understand the men he handles and to do this he must be one of them, be able to think as they think, and yet at the same time not lose his personality as an administrator and in effect an employer. In all probability this is the most difficult of all engineering functions and no man should undertake it who does not have a great "love" for his fellow men. The only way to acquire the mental flexibility of looking at one's actions from the point of view of the workman is to have been a workman oneself. No amount of theoretical training will give this faculty. It is therefore suggested that on leaving the secondary school with learning to the standard of the London matriculation, the boy at the age of 17 should go straight into an engineering works for a comprehensive apprenticeship course of four years, doing exactly the same work as a boy training to be a skilled workman but on a wider basis and with the requirement that he should study in his spare time by means of part-time day (one day per week) and evening classes. The student must attain a theoretical standard not less than that required of the applicational engineer. Not many, unfortunately, survive, but those that do and have a suitable character are superexcellent. Few are able to complete their theoretical training within the four years (the writer actually took six) but on completion of their four-year apprenticeship, the students will be admirably suited for the position of junior production engineer or time-study engineer and will be able to complete their technical training in their spare time. It is essential that the firm should give sympathetic consideration for time off to sit for examinations, in addition to normal holidays, in spite of the fact that the young man is virtually no longer a trainee but a normal member of the staff.

If the operational engineer wishes to take up generation, transmission, and distribution in electrical engineering or traction work, he will endeavour to obtain a junior position with a utility company or an electrified railroad, on the completion of his apprenticeship, but the general scheme of training is the same.

Postgraduate training can be also given to this type of engineer with greater benefit than to any other, but how this should be carried out is a problem for industry and the universities to solve together. And on their solution as to how to give this postgraduate training to applicational and operational engineers perhaps depends the future of engineering and consequently the whole of our civilization.

The training outlined here for any of the three types is undoubtedly arduous. Many will fall out along the way and provide the necessary technical intermediate staff but those that do survive will be able to carry on the great tradition of engineering and continue as the mainstay of our present civilization and culture.

Yours very truly,

N. V. Pestereff

(Purchasing assistant electrical engineer, The Canadian and General Finance Company, Ltd., London, England)

Personal Items

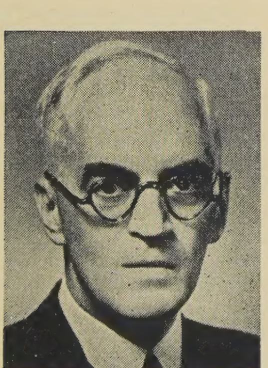
E. S. Lee (A'20, F'30) engineer in charge, general engineering laboratory, General Electric Company, Schenectady, N. Y., has been appointed chairman of the Institute's committee on constitution and bylaws for the year 1939–40. He has been a member of the committee since 1937. Mr. Lee, who was born at Chicago, Ill., November 19, 1891, received the degree of bachelor of sci nce in electrical engineering at the University of Illinois in 1913 and that of master of science in electrical engineering from Union College in 1915. From 1913 to 1916 he was an instructor in electrical engineering at Union College and a laboratory assistant at the General Electric Company in Schenectady, N. Y. He was with the Locomotive Stoker Company, Chicago, Ill., 1916–17, and during the next year was in charge of machine-gunnery at the United States Army school of military aeronautics at the University of Illinois, Urbana. Since 1918 he has been affiliated continuously with General Electric, becoming assistant engineer of the general engineering laboratory in 1928 and assuming his present position in 1931. He has been a director of the Institute, and chairman of the AIEE Schenectady Section. He has served on the executive, headquarters, Sections, and meetings and papers (now technical program) committees, and on the committees on membership (chairman 1933–36), finance (chairman 1936–37), and transfers (chairman 1937–39), and has been Institute representative on the division of engineering and industrial research of the National Research Council. At present he is a member of the committees on instruments and measurements, research, planning and coordination, the Edison Medal committee, and now and in the past has been active on special committees. Mr. Lee is also active in committee work in The American Society of Mechanical Engineers, American Society for Testing Materials, and American Standards Association.

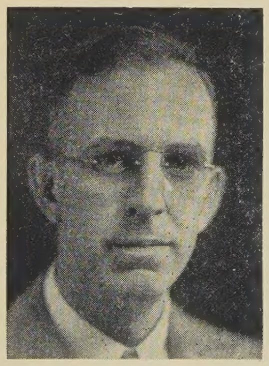
J. W. Barker (M'26, F'30) dean of engineering, Columbia University, New York, N. Y., has been appointed chairman of the technical program committee and the committee on award of Institute prizes of the AIEE for 1939–40. He has been a member of the first since 1932 and of the second since 1937. Dean Barker was born June 17, 1891, at Lawrence, Mass., and received the degrees of bachelor of science in electrical engineering (1916) and master of science in electrical engineering (1925) from Massachusetts Institute of Technology. He served in the Coast Artillery Corps of the United States Army as artillery engineer and adjutant from 1916 to 1925, during part of the time being officer in charge of civil affairs of the American forces in Germany. Appointed associate professor of electrical engineering at Lehigh University, Bethlehem, Pa., in 1925, he became professor and head of the department in 1929. Since 1930 he has been professor and dean of the faculty of engineering at Columbia University. He has served on the Institute's committee on production and application of light and is at present a member of the publication, planning and co-ordination, Edison Medal, and education committees, having been chairman of the last-named 1937–39. He is Institute representative on the Iwadare Foundation and the United States national committee of the International Commission on Illumination. He is a member of several other technical societies and has been active in the division of engineering and research of the National Research Council.

F. Ellis Johnson (A'13, F'31) dean of the college of engineering, University of Wisconsin, Madison, has been appointed chairman of the Institute's committee on education for 1939–40. He has been a member of the committee during 1933–35 and since 1936. Born May 27, 1885, at LeRoy, Mich., he received the degrees of bachelor of arts (1906) and electrical engineer (1909) from the University of Wisconsin. Following a period of employment in substation construction in the western United States and Canada, he became an instructor in electrical engineering at The Rice Institute, Houston, Tex., in 1912. He entered the electrical-engineering department of the University of Kansas, Lawrence, as an instructor in 1915, and advanced through the grades of assistant professor, associate professor, and professor, to become head of the department in 1928. In 1930 he went to Iowa State College, Ames, as head of the department of electrical engineering, and in 1935 he became dean of the college of engineering, University of Missouri, Columbia, assuming his present position at Wisconsin in 1938. He has been a director of the Institute and member of the committees on membership and on Student Branches (chairman 1936–38). He is currently a member of the committee on electrical machinery, and an Institute representative on the Engineers' Council for Professional Development.

W. F. Davidson (A'14, F'26) director of research, Consolidated Edison Company of New York, Inc., New York, N. Y., has been appointed chairman of the AIEE committee on research for 1939–40. He has been a member of the committee since 1925. Born at Commonwealth, Wis., October 21, 1890, he received the degrees of bachelor of science (1913) and master of science (1920) from the electrical-engineering department of the University of Michigan. He was with the Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa., 1914–16, and became an instructor at the University of Michigan, Ann Arbor, in 1916, returning in 1919 after two years' service in the United States Army. He became associate professor in 1920. In 1922 he went with the Brooklyn, N. Y., Edison Company to organize its research department, which was expanded under his direction to include research and testing activities in all the company's fields of interest. When the Brooklyn Edison Company became a part of Consolidated Edison of New York in 1936 he assumed his present position. He is a member of the committees on the award of Institute prizes and on basic sciences (formerly committee on electrophysics, of which he was chairman 1934–36).

J. C. Parker (A'04, F'12) vice-president, Consolidated Edison Company of New York, Inc., New York, N. Y., and junior past-president of the AIEE, has been appointed chairman of the Institute's committee on planning and co-ordination for the year 1939–40. Born at Detroit, Mich., April 15, 1879, he received the degrees of bachelor of science in mechanical engineering (1901), master of arts (1902) and electrical engineer (1904) from the University of Michigan,


J. C. PARKER


W. F. DAVIDSON


J. W. BARKER

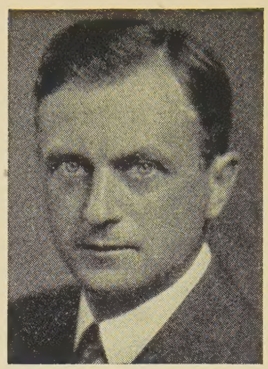

F. ELLIS JOHNSON


E. S. LEE

A. L. POWELL

W. S. FINLAY, JR.

F. O. McMILLAN



H. S. OSBORNE

D. W. ATWATER

and the honorary degree of doctor of engineering from Stevens Institute of Technology in 1935. He was in the testing department of the General Electric Company, Schenectady, N. Y., 1902–3, and the following year was an instructor in mechanical and electrical engineering at Union College in Schenectady. In 1904 he became assistant to the engineer in charge of construction and design of the Ontario Power Company's plant at Niagara Falls, and the following year assistant to the chief engineer of the construction company building the lines of the Niagara, Lockport, and Ontario Power Company. As mechanical and electrical engineer he was transferred from Buffalo to Rochester, N. Y., by the construction company in 1907, and in 1908 was placed in charge of the engineering department of the Rochester Railway and Light Company. He was appointed head of the department of electrical engineering of the University of Michigan in 1915 and continued there until 1922, when he became associated with the Brooklyn, N. Y., Edison Company as electrical engineer. He became vice-president in charge of engineering in 1926 and president of the company in 1932, and in 1936, when the company became a part of Consolidated Edison of New York, became vice-president of the latter organization. He served the Institute as president, vice-president, member of the committees on Student Branches, education (chairman 1919–20), Sections, meetings and papers (now technical program committee), standards, power generation, power transmission and distribution, electrical machinery, the engineering profession, legislation affecting the engineering profession, and Lamme Medal committee, and as Institute representative on the American Standards Association. He is at present a member of the executive and Edison Medal committees, the committee on code of principles of professional conduct, and Institute representative on the John Fritz Medal board of award, and the division of engineering and industrial research of the National Research Council.

F. O. McMillan (A'14, F'32) head of the electrical-engineering department, Oregon State College, Corvallis, has been appointed chairman of the AIEE committee on transfers for 1939–40. He has been a member of the committee since 1936. Born at Albia, Iowa, May 12, 1890, he received the degrees of bachelor of science in electrical engineering (1912) from Oregon State College, and master of science in electrical engineering (1919) from Union College. From 1913 to 1920 he was employed by the General Electric Company, Schenectady, N. Y. Appointed assistant professor of electrical engineering at Oregon State College in 1920, he became associate professor in 1923, research professor in 1930, and head of the department in 1938. He has also been consulting engineer for the United States Bureau of Fisheries, the Port of Portland, Ore., the Northwest Electric Light and Power Association, and other organizations. He has been a vice-president of the AIEE and has served on the committees on Student Branches and basic sciences, and is at present a member of the committees on research and on education. He is a member of several technical societies.

D. W. Atwater (A'24) manager of commercial engineering, lamp division, Westinghouse Electric and Manufacturing Company, Bloomfield, N. J., has been appointed chairman of the AIEE committee on production and application of light for the year 1939–40. He has been a member of the committee since 1935. Born August 14, 1894, at Newark, N. J., he received the degree of mechanical engineer from Stevens Institute of Technology in 1916, and became a factory engineer for the Edison Lamp Works, General Electric Company, Harrison, N. J. He was with the United States Army during 1917–1919, in the latter year becoming a specification engineer for the Western Electric Company, New York, N. Y. In 1920 he went with the lamp division of the Westinghouse Company, becoming assistant manager of the commercial engineering department in 1933 and manager in 1934. He has long been active in the Illuminating Engineering Society, of which he has been president and general secretary, and has been chairman of the illuminating group of the AIEE New York Section.

H. S. Osborne (A'10, F'21) operating results engineer, American Telephone and Telegraph Company, New York, N. Y., has been appointed chairman of the AIEE finance committee for 1939–40. He has formerly served on the standards, education, communication, and publication committees and as Institute representative on the United States national committee of the International Electrotechnical Commission. At present he is a director of the Institute, member of the technical program and award of Institute prizes committees, of both of which he was chairman 1936–39, and of the executive, headquarters, Edison Medal, and planning and co-ordination committees, and the committees on Institute policy and on legislation affecting the engineering profession, and Institute representative on the council of the American Association for the Advancement of Science, the Alfred Noble prize committee of the American Society of Civil Engineers, and the standards council and electrical standards committee of the American Standards Committee. A biographical sketch of Mr. Osborne appeared in the May issue, page 227.

W. S. Finlay, Jr. (A'18, F'21) has been appointed a vice-president of the J. G. White Engineering Corporation, New York, N. Y. Since 1927 he had been president of The West Penn Electric Company, New York. Born at Hoboken, N. J., August 18, 1882, he received the degree of mechanical engineer from Cornell University in 1904. From 1904 to 1909 he was an assistant engineer in the motive power department of the Interborough Rapid Transit Company, New York. During the next year he was engaged in engineering construction for the J. G. White company and the New England Engineering Company, New Haven, Conn., and from 1910 to 1915 in managerial work for E. and W. S. Finlay, New York. He returned to the IRT in 1915 as construction engineer, and was superintendent of motive power 1917–20. He became vice-president of the American Water Works and Electric Company in 1920, continuing in that position until he assumed the presidency of its subsidary, The West Penn Power Company, in 1927. He is a member of The American Society of Mechanical engineers.

A. L. Powell (A'13, F'26) supervising engineer, incandescent lamp department, General Electric Company, New York, N. Y., has been appointed chairman of the AIEE board of examiners for 1939–40. He has been a member of the board since 1929. Born April 6, 1889, at Brooklyn, N. Y., he received the degree of electrical engineer from Columbia University in 1910, and the same year was employed by the Edison lamp works of General Electric at Harrison, N. J. From 1911 to 1924 he was first assistant to the illuminating engineer, engaged in design and research work. During 1924–25 he was special representative in Europe for International General Electric

Company, and in 1925 he became manager of the engineering department of the Edison lamp works. He was transferred to his present position in 1932. He was a member of the United States Committee of the International Commission on Illumination at its meeting in Geneva, Switzerland, in 1924, and at its meeting in Germany in 1935, and a member of the United States Commission to the Paris Exposition in 1925. He is a member of the AIEE committee on production and application of light (chairman 1935–37) and a past-president of the Illuminating Engineering Society.

H. L. Hazen (A'26) head of the department of electrical engineering, Massachusetts Institute of Technology, Cambridge, Mass., has been appointed chairman of the AIEE committee on basic sciences for 1939–40. He became a member of the committee in 1938. Born August 1, 1901, at Philo, Ill., he studied electrical engineering at Massachusetts Institute of Technology, receiving the degrees of bachelor of science (1924), master of science (1929), and doctor of science (1932). He joined the teaching staff of MIT in 1926, becoming associate professor in 1936, and professor and head of the department in 1938. During 1934–35 he served as exchange professor at Ohio State University, Columbus. In addition to his academic work, he has had experience in the laboratories of the General Electric Company and the American Telephone and Telegraph Company. He received the 1934 Levy Gold Medal of the Franklin Institute for technical papers on the theory and design of servo-mechanisms.

I. F. Kinnard (A'21, M'28) executive engineer, West Lynn works, General Electric Company, Lynn, Mass., has been appointed chairman of the AIEE committee on instruments and measurements for the year 1939–40. He has been a member of the committee since 1927. Born in Ontario, Can., September 29, 1891, he received the degree of bachelor of science in electrical engineering from Queen's University, and did advanced work both at Queen's and at the University of Glasgow. After service overseas as an officer in the Canadian Engineers, he became a research engineer for Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1920. He went to the West Lynn works of General Electric as an electrical engineer in 1923, where he did research on electrical instruments. He was appointed assistant chief engineer in 1923, and later executive engineer.

C. R. Beardsley (A'08, F'30) manager, contract control and inspection department, Consolidated Edison Company of New York, Inc., New York, N. Y., has been appointed chairman of the Institute's committee on legislation affecting the engineering profession, for the year 1939–40. He has been a member of the committee since 1937. A director of the Institute, Mr. Beardsley is also a member of the Edison Medal and technical program committees, and was chairman of the special committee on model registration law. A biographical sketch of him appeared in the April issue, page 183.

E. E. George (A'20, F'36) has been appointed a member of the engineering staff of Phoenix Engineering Corporation, New York, N. Y., a subsidiary of Ebasco Services, Inc. He was formerly superintendent of system operation, Tennessee Electric Power Company, Chattanooga. A biographical sketch of Mr. George appeared in the March issue, page 135.

K. T. Compton (F'31) president, Massachusetts Institute of Technology, Cambridge, has been appointed to the newly formed War Resources Board, which is designed to plan the mobilization of the economic and industrial resources of the United States in the event of war.

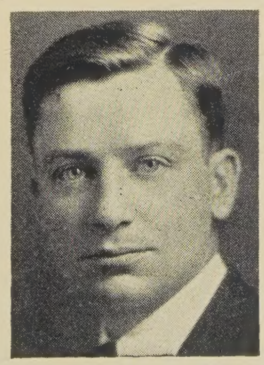
T. S. Taylor (M'21) has become a member of the teaching staff of Newark College of Engineering, Newark, N. J. He was formerly manager of the engineering laboratory and experimental department, Diehl Manufacturing Company, Elizabethport, N. J.

Chester Russell, Jr. (A'29, M'34) formerly associate professor and head of the department of electrical engineering, University of New Mexico, Albuquerque, has become associate professor of electrical engineering at the University of Denver, Denver, Colo.

E. M. Manos (A'38) has been employed as electrical draftsman and estimator by the North State Electric Company, Chicago, Ill.

W. S. Gifford (A'16) president, American Telephone and Telegraph Company, New York, N. Y., has been appointed a member of the War Resources Board, recently organized to plan mobilization of the economic and industrial resources of the United States in the event of war.

C. R. BEARDSLEY



H. L. HAZEN

I. F. KINNARD

Obituary

Glen Harry Smith (A'20, M'26) assistant superintendent, municipal electric power generating and distributing system, City of Seattle, Wash., died at Louisville, Ky., September 10, 1939. He was born March 31, 1885, at Loveland, Colo., and studied at the University of Washington, receiving the degrees of bachelor of arts (1909) and bachelor of science in electrical engineering (1910). He had been employed by the lighting department of the City of Seattle since 1909, having been an oiler, substation operator, wiring draftsman (1912), engineer, overhead distribution (1917), and engineer, outside construction, from 1918 until his death. Since 1917 he had been in charge of operation and construction of distribution and transmission for the Seattle municipal system. He was vice-chairman of the AIEE Seattle Section.

David Rhett Pringle (A'07) utilities superintendent, City of Thomasville, Ga., died August 4, 1939. He was born in Leon County, Florida, August 24, 1882, and graduated with the degree of bachelor of science in electrical engineering at the Georgia Institute of Technology in 1904. He spent three months in the student course of Western Electric Company, New York, and from October 1904 to January 1906 was employed by the Gray National Telantograph Company, New York. He became superintendent of the municipal electric light plant at Thomasville in January 1906, when the plant was first placed under municipal operation, and had charge of the development of the expanding system until his death.

Charles Arba Storms (A'26, M'36) electrical engineer, Michigan Limestone and Chemical Company, Rogers City, died August 21, 1939. Born September 23, 1899, at Fargo, N. Dak., he received the degree of bachelor of science in electrical engineering from California Institute of Technology in 1923. He was employed in the test department of the General Electric Company, Schenectady, N. Y. from 1923 to 1929, during the last two years of that time as foreman of the construction section. Since 1929 he had been electrical engineer for the Michigan Limestone and Chemical Company, having charge of design, construction, and operation of various electrical installations.

Adhemar Machado de Sousa (A'28), first assistant engineer, Sao Paulo Tramway, Light, and Power Company, Sao Paulo, Brazil, died recently, according to information received at AIEE headquarters. He was born December 10, 1903, at Santos, Sao Paulo, Brazil, and graduated with the degree of electrical engineer from the Polytechnic School of Sao Paulo in 1927. In 1928 he was employed as apprentice engineer in the department of electrical studies and investigations of the Sao Paulo Tramway, Light, and Power Company, and continued with the company until his death.

Membership

Recommended for Transfer

The board of examiners, at its meeting on September 14, 1939, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Cadwallader, J. A., engineer of transmission and outside plant, The Bell Telephone Company of Pennsylvania, Pittsburgh.
Edmondson, F. C., general manager, City of Perth Electricity and Gas Department, Perth, Western Australia.
MacGregor, J. R., chief engineer, The Bell Telephone Company of Pennsylvania, Pittsburgh.
Mier, C. W., area engineer, Southwestern Bell Telephone Company, Dallas, Tex.

4 to Grade of Fellow

To Grade of Member

Adler, L. E., communication engineer, Magnolia Pipe Line Company, Dallas, Tex.
Chiles, J. H., section engineer, Westinghouse Electric and Manufacturing Company, Sharon, Pa.
Dalziel, C. F., assistant professor, University of California, Berkeley.
Dunham, H. E., assistant manager, patent department, General Electric Company, Schenectady, N. Y.
Fiedler, G. J., instructor in electrical-engineering department, Union College, Schenectady, N. Y.
Hobson, L. S., managing engineer, General Electric Company, Philadelphia, Pa.
Jadeja, K. K. R., chief electrical engineer, Nawanagar State Power House, Jannagar, India.
Kelm, A. C., superintendent of electric service, Utah Power and Light Company, Salt Lake City.
Nartker, L. J., electrical engineer, Sunlight Electric Division of General Motors Corporation, Warren, Ohio.
Plomasen, C. G., electrical engineer, Eastman Kodak Company, Rochester, N. Y.
Sandberg, S. I., electrical-engineering designer, City of San Francisco, Calif.
Scholz, H. J., supervising electrical engineer, Commonwealth and Southern Corporation of New York, Birmingham, Ala.
Weaver, E. F., division superintendent, Pennsylvania Power and Light Company, Allentown.

13 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Names of applicants in the United States and Canada are arranged by geographical Districts. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before October 31, 1939, or December 31, 1939, if the applicant resides outside of the United States or Canada:

United States and Canada

1. North Eastern

Gifford, F. A., New England Telephone and Telegraph Company, Boston, Mass.
Hammond, J. W., Jackson and Moreland, Boston Mass.
Osborn, A. L., Orange and Rockland Electric Company, Monroe, N. Y.
Sheals, V. A. (Member), General Electric Company, Schenectady, N. Y.

2. Middle Eastern

Hudson, H. A., Southern Railway System, Washington, D. C.
McOrlly, J. (Member), Edwin L. Wiegand Company, Pittsburgh, Pa.
Tomb, R. N., 113 Hammer Avenue, Johnstown, Pa.

3. New York City

Adamson, A. A., Bell Telephone Laboratories, Inc. New York, N. Y.
Cawthorne, T. S., Weston Electrical Instrument Corporation, Newark, N. J.
Hughes, K. E. (Member), The Hickok Electrical Instrument Company, Cleveland, Ohio, New York, N. Y.
Hyde, G. G. (Member), Consolidated Edison Company, New York, N. Y.
Oberkirk, W. C., Wilbur B. Driver Company, Newark, N. J.

4. Southern

Storer, S. B., Trumbull Electric Manufacturing Company, Ludlow, Ky.
Wilder, A. N., Tampa Electric Company, Plant City, Fla.

5. Great Lakes

Beckjord, P. A., Jr., Westinghouse Electric and Manufacturing Company, Chicago, Ill.
Hudson, M. B., Illinois Iowa Power Company, Edwardsville, Ill.
Johnson, F. M., Swift and Company, Chicago, Ill.
Sutherland, R. O., United Light and Power Service Company, Chicago, Ill.

6. North Central

Mitchel, G. W., Black Forest Fox Ranch, Monument, Colo.

7. South West

Conner, J. M., Nevada Consolidated Copper Corporation, Hurley, N. Mex.
Hahn, H. E. (Member), Federal Engineering and Construction Company, Kansas City, Mo.
LeDoux, A. E., El Paso Electric Company, El Paso, Tex.
Riegel, P. R., Sun Oil Company, Beaumont, Tex.
Starcke, O. A., United Light and Power Service Company, Kansas City, Mo.

8. Pacific

Koch, C. R., Westinghouse Electric and Manufacturing Company, San Francisco, Calif.
Stahl, W. F., Jr., Stahl Ranch Company, Fallbrook, Calif.

9. North West

Bachman, E. (Member), General Electric Company, Salt Lake City, Utah.

Total, United States, 27

Elsewhere

Chandrasekharan, V. A., care V. N. Raja and Company, Vellore, South India.
Kuramoto, H. H., Hawaiian Sugar Company, Makaweli, Kauai, T. H.
Page, G. B. (Member), Indian Cable Company, Ltd., Calcutta, India.
Rampal, J. N., Punjab Electric Power Company, Ltd., Montgomery, Punjab, India.
Richardson, R. C. H., Metropolitan Vickers Electric Company, Ltd., Glasgow, C 2, Scotland.
Seshachar, K. V., Tata Iron and Steel Company, Ltd., Jamshedpur, India.

Total, elsewhere, 6

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the addresses as they now appear on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Crawford, Wade P., Box 364, Coeur D'Alene, Idaho.
Doherty, Joseph F., 901 Hill St., Wilkinsburg, Pa.
Ebert, Kenneth W., 776 N. Cass St., Milwaukee, Wis.
Hall, John R., c/o Patrick Tyrrell Drilling Co., Cotton Exchange Bldg., Houston, Texas.
James, George Hazard, Jr., 7 Meikle Ave., Newport, R. I.
Keiser, M., 1841 Broadway, New York, N. Y.
Lovett, Morris, Diehl Manufacturing Company, Elizabethport, N. J.
McCarthy, C. C., c/o Westinghouse Electric and Manufacturing Co., 814 Ellicott Square, Buffalo, N. Y.
Modisette, M. H., 4514—16th St., N. E., Seattle, Wash.
O'Fiel, J. C. Dudley, Jr., 1214 Chartres St., Houston, Texas.
Pyne, Arnold N., 627 Third St., Niagara Falls, N. Y.
Sanchez, Hector M., 12 De Diegos Ave., Santurce, Puerto Rico.
Strauss, Walter A., 39 West 69th St., New York, N. Y.
Taylor, Richard V., Hotel Wood, Jefferson & Clinton St., Syracuse, N. Y.
Williams, Robert E., Jr., 1038 Wendell Ave., Schenectady, N. Y.

15 Addresses Wanted

Engineering Literature

New Books in the Societies Library

Electrical engineers may be interested in the following new books, which are among those recently received at the Engineering Societies Library, New York, N. Y. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the preface of the book in question.

CO-OPERATION IN RESEARCH. By the Staff Members and Research Associates of the Carnegie Institution of Washington, Washington, D. C. 1938. 782 pages, illustrated, 10 by 7 inches, paper, $4.50; cloth, $5.00. This volume of papers written by members and research associates of the Carnegie Institution of Washington commemorates the retirement of President John C. Merriam. Among the papers of special interest to electrical engineers may be mentioned: An Adventure in Scientific Collaboration, by Arthur L. Day; Magnetism and the Atomic Nucleus, by M. A. Tuve, L. R. Hafstad, and N. P. Heydenburg; Universal Aspects of Atmospheric Electricity, by O. H. Gish; The General Magnetic Field of the Earth and Its Secular Variation, by J. A. Fleming; The Ephemeral Variations of the Earth's Magnetism, by L. V. Berkner and A. G. McNish; The Scientific Basis of the History of Science, by George Sarton.

REPORTS ON PROGRESS IN PHYSICS. Volume 5. Edited by A. Ferguson. London, S.W. 7, The Physical Society; Cambridge, England, University Press, 1939. 445 pages, illustrated, 10 by 7 inches, cloth, 20s. Continuing the series of reports issued by the Physical Society, the present volume deals with advances in physical science up to the end of 1937. It includes reviews of the work in general physics, sound, heat, astronomy, meteorology, optics, spectroscopy, electric-wave filters, and atomic physics; and more comprehensive articles on the adsorption theorem of J. W. Gibbs, liquid-state theories, plastics in industrial physics, instrumental aids for defective bearing, soft X-ray spectroscopy, the use of X rays and Y rays in medicine, absolute electrical measurements, the Geiger counter, quantum mechanics, and physics teaching in schools.

REGULATIONS AND ORDERS RELATING TO SAFETY AND HEALTH. Mines Department, Great Britain Coal Mines Act, 1911. 1939 edition. 199 pages, tables, 10 by 6 inches, paper, 1s. 6d. (Obtainable from British Library of Information, 50 Rockefeller Plaza, New York, $0.45.) Intended primarily as a book of reference for mine officials, students of mining, etc., and contains, with a few exceptions, all the orders and regulations which are of general application in relation to matters of safety and health in the working of mines. Topics covered include first-aid and rescue methods, lighting, mechanical equipment, fire-fighting, signaling apparatus, explosives, and certificates of qualification for various jobs.

THE THEORY OF FUNCTIONS. By E. C. Titchmarsh. Second edition. New York, Oxford University Press, 1939. 454 pages, tables, 9 by 6 inches, cloth, $8.50. These introductory chapters to various branches of the theory of functions are intended to bridge the gap between the elementary textbooks and the systematic treatises. Chapter topics include infinite series, analytic functions, residues, analytic continuation, the maximum-modulus theorem, conformal representation, power series, infinite functions, differentiation, Lebesgue integration, and Dirichlet and Fourier Series. Bibliography.

USES AND APPLICATIONS OF CHEMICALS AND RELATED MATERIALS. Edited by T. C. Gregory. New York, Reinhold Publishing Corporation, 1939. 665 pages, 9 by 6 inches, cloth, $10.00. Over 5000 chemicals, drugs, metals, oils, and so forth, are listed alphabetically under their common names, each accompanied by a broadly classified list of present uses and potential applications. English synonyms, corresponding foreign names, and some patent references are also given. At the back of the book the synonyms and cross references are listed alphabetically.

MITTEILUNGEN AUS DEN FORSCHUNGSANSTALTEN, Bd. 7, Heft 3, April 1939, pages 41–66. Berlin, VDI-Verlag, 1939. Illustrated, 12 by 8 inches, paper, 2.90 rm. The three articles contained in this research communication deal respectively with the weldability of structural steel, with cog-wheel drives for electrically driven rolling-mills, and with the determination of wind loads on wide-span roofs by the use of a model.